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ING AND DELINEATION OF SPECIAL USAGE LANES

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January 1982

Final Report

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FOREWORD

This report is one of a series of reports resulting from the study, "Signing and Delineation for Special Usage Lanes." The report will be of interest to enforcement officials and to transportation engineers who are considering the implementation of special lanes for buses and carpools.

The research resulted in recommendations for signing and delineation systems for nine different classes of special use lanes. For each class, the information requirements together with the signing/marking mechanisms are presented in sufficient detail to permit their adaption to specific sites while at the same time ensuring a degree of standardization.

This volume documents the literature review and the information requirements analysis which led to the development of signing and delineation alternatives. Sign wording and symbol alternatives were studied in one series of four experiments and alternative lane marking concepts were studied in a second series of experiments. Conclusions which will be of interest in the development of future signing and marking standards are presented.

One copy of this report is being sent to each FHWA regional office, FHWA division, and State highway agency. The division and State copies are being sent directly to the division office.

Charles F. Scheffey
Director, Office of Research

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16. Abstract

Special usage lanes (SULs) are those roadway lanes dedicated to particular vehicle types or to unique operating characteristics. The most common usage is for high occupancy vehicles (HOVs-buses and carpools). In this report SULs and HOV lanes are used interchangably and denote the same concept.

The energy shortages of the 1970's brought a proliferation in the number of SULs and considerable variation in the signing and delineation of these lanes could be found among regions, among cities and even within metropolitan areas. Recognizing the need for more uniformity in signing and marking systems, this research had as its objectives:

- o Determination of the information requirements of users and non-users of SULs.
- o Development of signing and delineation systems to meet the information requirements.
- o Evaluation of the efficiency of the developed signing and delineation systems.

The objectives were achieved through literature search, analyses of SULs across the country and development of initial SUL information systems. The systems were evaluated through 13 laboratory and closed field experiments. The laboratory findings and several SUL information systems were then verified through operational field studies.

This volume, the second in the series, describes the SUL inventory, the site visits, information analysis and development of initial signing systems for SULs. The others in the series are:

Volume No.	FHWA No.	Short Title
1	FHWA/RD-81/062	Executive Summary
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CHAPTER 1
INTRODUCTION

In the late 1950s and early 1960s the answer to traffic congestion was simply to build more roads. Soon thereafter this trend reversed as land acquisition and construction costs soared, public opinion shifted, and energy conservation became a national necessity. The need to increase roadway-carrying capacity did not diminish, but more emphasis had to be given to improving the performance of existing facilities.

Since 1950 there has been a small, but slowly growing, number of roadway lanes dedicated to particular vehicle types or to unique operating characteristics. Such lanes proliferated in the 1970s, and continued growth of these special usage lanes (SULs) appears likely during the coming decades. This definition does not adequately explain the wide variety of special uses traffic engineers have created for urban, rural, arterial, and freeway type lanes. Table 1 illustrates the SUL definition by examples.

Generally, SULs have been created by state and local traffic engineers to meet specific, often unique, transportation needs. Because of their individuality, SULs cover a spectrum of restrictions, operating rules, geometrics, and signing and delineation.

An ever-present concern in highway design and operation is to present drivers with legible, understandable, credible information at appropriate places along the road. One accepted principle in information system design is that driver confusion will be minimized if signs and markings conveying similar (or identical) messages are the same wherever seen across the country.

Table 1

Examples of Special Usage Lanes (SULs)

Type of Lane Operation or Restriction	Other Name and/or Acronym for the SUL
Buses and carpools are only vehicles allowed to use the lane	Concurrent flow high occupancy vehicle (HOV) lane
Buses travel in a lane in the opposite direction from general traffic	Contra-flow HOV lane
Lanes go in one direction part of the day and the other direction the rest of the day	Reversible lanes
Only certain classes of vehicles may use certain lane(s)	Restricted lanes
Certain lanes may not have access to all interchanges	Express lanes
Center lane used only for left turns	Turn lane or bay
Right lane on hill for slow-moving vehicles	Slow vehicle lane

However, before standardizing and demanding compliance with a particular type of information system, there should be some assurance or evidence that the system will function as intended. If all the goals of the information system are not met, the system should be modified to improve performance.

This report deals with just such a situation. Signing and delineation standards for various types of SULs have been promulgated in the Manual on Uniform Traffic Control Devices only since 1974 (FHWA, 1975). As the findings of this project demonstrate, there is considerable variation in special usage lane signing and marking among regions of the country, among cities, and even within metropolitan areas. Thus, developing and establishing effectiveness for SUL signing and delineation which can be consistently applied to SULs nationwide is critical to assuring efficient and safe operation of this rapidly expanding type of highway facility.

Overview of the Project Structure

The project described in the three volumes of this report focused on meeting the need for standard special usage lane signing and delineation. Specifically, the project objectives were to:

- Determine the information requirements of users and non-users of special usage lanes
- Develop signing and delineation systems to meet the information requirements
- Evaluate the efficiency of the developed signing and delineation systems.

To accomplish the stated objectives, six tasks were performed:

- Task 1 was a literature review and information requirements analysis.
- Task 2 was the laboratory study of various signing system components.
- Task 3 was the development and laboratory comparison of alternative delineation systems.
- Task 4 was for planning field evaluations of the signing and delineation systems.
- Task 5 was the conduct of field evaluation studies.
- Task 6 was preparation of the final report.

The procedures used and results from these tasks are documented in three volumes. Volume I is an executive summary covering the entire project; Volume II covers Tasks 1, 2, and 3; and Volume III describes Tasks 4 and 5, as well as suggestions for implementation and further research.

CHAPTER 2
LITERATURE REVIEW

The resource literature accumulated for the project is documented in this chapter. This literature base was used in support of the project objectives, which were:

- Determine the information requirements of users and non-users of special usage lanes
- Develop signing and delineation systems to meet the information requirements
- Evaluate the efficacy of the developed signing and delineation systems.

The products of the search are a synthesis of the literature, a subject-by-document matrix, and a bibliography of all reports reviewed.

Purpose of the Literature Search

Literature resources were developed to serve this project in four ways:

- Inventory existing special usage lanes
- Review recent developments in signing and delineation research
- Review recent developments in driver related information processing research
- Review information analysis techniques.

Literature Search Methods and Documentation

Five literature content areas were derived based on the above purposes:

- Descriptions of various special usage lanes, e.g., reversible, bus priority
- Traffic control devices as used in special usage lanes
- Signing and delineation research relevant to SULs
- Driver information processing research relevant to SULs
- Research on or the application of information and task analysis technology.

For each of these areas the existing libraries of BioTechnology and the Institute for Research were searched. Where the literature on a topic was not complete, a computer search was done. Four searches were conducted, as listed below:

Search Topic	Purpose	Literature Base Searched
Traffic control devices in special use lanes	Complete 10 year review	TRIS*
Special use lane facilities	Complete 10 year review	TRIS
Signing and delineation	2 year update	TRIS
Driver perception and information processing	3 year update	TRIS and APA**

*TRIS = Transportation Research Information System

**APA = American Psychological Association

To supplement the above searches, requests were made of selected federal, state, and city traffic engineers working with special use lanes to provide any reports generated for state or local projects. Finally, as documents were acquired, bibliographies were checked for references as yet uncovered in the other search efforts.

Synthesis of Findings

In reviewing documents from the five content areas above, four basic categories of documents emerged:

- SUL-related documents: Traffic operational descriptions of SUL sites, facilities; guidelines to effective operations, SUL field research
- Driver perceptions of novel system displays (i.e., SULs)
- Driver information processing needs
- Guidelines to visual display design.

In the entire search process, reports were represented ranging from facility status reports to general research studies, theoretical discussions to official standards and guidelines. A summary of findings from each of the basic categories above follows.

SUL-Related Documents

Many reports have been issued (e.g., Rothenberg, 1977; UMTA, 1972; Simkowitz, 1978) that detail the existence and operating characteristics of SUL facilities. Discussions center around descriptions of the site and its overall effectiveness. Measures of effective operation are some form of the following parameters:

Environmental Benefits

- Energy conservation from fewer vehicles and smoother flow of vehicles, increased passenger miles per gallon (i.e., Oregon DOT, 1978; Rothenberg, 1977)
- Air quality improvements (Horowitz & Kuhrtz, 1974; LaPlante, 1975)

Corridor Operational Improvements

- Return to more acceptable level of service (Oregon DOT, 1978)
- Avoidance of frustration of stop-and-go operations
- Decreased total travel time (increase average passenger speed)
- Increased movement of passengers per hour (Capelle et al., 1972; Carr, 1975; Crain, 1975; Simkowitz, 1978)

Transit System and User Benefits

- Additional revenue
- Reduction in personal travel costs (time and dollars)
- Higher service levels to the transit-dependent
- Improved transit reliability, and hence, reliance on transit services (Levinson et al., 1973)

Increased Use of Carpools and Vanpools

- Incentives provided, such as bypassing other traffic, decreased travel time, avoidance of stop-and-go congestion, cost discounts on toll facilities (Link, 1973; Morin, 1974; Rothenberg, 1977)

Cost Effectiveness of Implementation and Operation

- Short implementation time
- Easily modified or removed
- Relatively low cost
- Relatively minor maintenance time and cost (Public Technology, 1977; Brothers et al., 1975)

Safety

- No major increase in accident rates
- No increase in severity of accidents (Miller et al., 1979; Oregon DOT, 1978)

Other reports assessing existing facilities detail some of the shortcomings of their operations (i.e., Simkowitz, 1978, Taylor et al., 1974; Erdman & Panuska, 1976). Certain projects that involved the taking away of an existing lane from general traffic and rededicating it to high occupancy vehicles ended in public controversy and dispute (i.e., Santa Monica Freeway). Other projects were not particularly helpful in expediting traffic because the peak period was not congested enough (Erdman & Panuska, 1976).

After some of the initial SUL projects had been deployed and evaluated in these various cost/benefit analyses for road users, environment, etc., some guidelines began to emerge for future implementation based on experiences. The results of some projects (Simkowitz, 1978) began to point out weaknesses in safety, enforcement problems, and overall user acceptance (Department of Transportation, 1975). While most SUL deployments generally exhibit positive characteristics and benefits (Anonymous, 1973; Caltrans, 1975; Public Technology, 1977), caution must be exercised in specific cases to insure road user

and pedestrian safety (Miller et al., 1979). In addition, the SUL must have the support of local enforcement officials and the benefit of an advance public education campaign to acclimate users to its existence and purpose. Guidelines for deployment to consider safety, enforcement, and user acceptance have emerged in such reports as Safety Evaluation of Priority Techniques for High Occupancy Vehicles (Miller et al., 1979) and Enforcement Requirements for High Occupancy Vehicle Lanes (Miller & Deuser, 1976). In these reports recommendations and models for safety and enforcement procedures are given.

Recognition of the growing number of SUL facilities implemented and evaluated in the various cities has generated the need for a closer look at their operations. The need for effective safety precautions and enforcement provisions is acknowledged and documented. Except coincidental descriptions and photographs in various reports, little has been referenced of the signs and markings used to inform the driver of the existence and operating rules of the SUL facilities. Current national standards on traffic control devices for freeways and arterial streets are established by FHWA's Manual on Uniform Traffic Control Devices (MUTCD) (FHWA, 1975). The MUTCD has established special pavement markings and signing for preferential lane use control. Although these standards have been established, they are not uniformly applied, and an SUL on a freeway may have different requirements than one on an arterial (Miller et al., 1979). Similarly, an SUL on an arterial street could very well have additional signing requirements for turning and parking restrictions in order to improve traffic capacity and safety. Clearly, the driver's perceptual needs to negotiate the SUL facility are best met by signing and delineation in a uniform application. To begin the design and test of such uniform systems, the next body of literature was examined: underlying principles of driver perceptions of new information.

Human Engineering Guidelines
to Driver Perception of
Novel System Displays

Even though the literature predominantly evaluates special usage lanes in the terms noted above, a most important component of such facilities is the signing and delineation used to present guidance and navigational information to drivers. In the case of special usage lanes, this is particularly critical because certain classes of drivers or vehicles are not eligible to use certain lanes. Also, such lanes may flow in different directions, or be available for use, at different times of the day. This means that signing and delineation must provide considerable information beyond that normally found on regular arterials or freeways.

It is necessary to emphasize the adjective "special" when discussing the phenomenon of special usage lanes. This term is most often defined as "distinctive, uncommon, unique, of a kind different from others"; and as drivers first encounter these special usage lanes along the roadway, they are presented with an atypical experience. Eliciting correct behaviors from drivers unfamiliar with SULs is important but difficult. This is because the driver has been placed in a situation of temporary uncertainty; therefore, he is more prone to be distracted from control and guidance tasks. Decisionmaking takes more time since unfamiliar drivers bring minimal past experience to SULs, and have irrelevant or no expectancies.

During an encounter with an unfamiliar SUL, drivers are confronted with an entirely new roadway concept to which they must devote considerable attention. The complexity of processing SUL information within the given period of time for self-passage dictates that the driver's information needs be met by an

advanced information display. Once the new information is processed, uncertainty is reduced and communication has taken place (DeGreene, 1970). The driver is then free to shift his attention back to navigational and control tasks.

The necessity of an early warning system is predicated on the assumption that the information regarding the SUL will be perceived and integrated into the individual's expectancies in a holistic manner. The task involves discrimination of a figure ground relationship, signal from noise. Essentially, the driver seeks a good "Gestalt" to which he can divert minimal processing energies to this situation, learn the nature of it, formulate a response, and return his attention to subsequent areas. The less the amount of information needed to define a given figure compared to other alternatives, the more likely the figure will be perceived (Hochberg & McAllister, 1953).

Drivers, as all information processors, tend to group elements of systems as a deliberate strategy to form an easily intelligible precept (Pomerantz & Schwaitzberg, 1975). The presentation of the SUL system of information must conform to this need. It best serves the discrimination of the array if the driver is: first, oriented to the system; second, presented its elements consistently and with a high degree of internal redundancy; and third, given closure to know that this given figure is complete and resolved (DeGreene, 1970). Any ambiguity in presentation of the system elements has been shown to depress the driver's confidence in correct decisionmaking (Rotton, 1973).

The importance of meeting the driver's perceptual needs to allow effective assimilation of the SUL information cannot be overemphasized, since this task demands cognitive attention. Attention consists of selecting that to which information

processing capacity should be allocated (Smith, 1974). A degraded presentation of information that does not encompass the three elements discussed above--orientation/consistent presentation/closure--will cause the driver to be defensive and in a disoriented frame of reference, since the signals that he is receiving are not coming across as clearly discriminable from noise, i.e., not a good "Gestalt" (Banks & Prinzmetal, 1976). Psychological models of selective attention, signal detection, and effective discrimination of systems all emphasize a singular point: Cognitive processing of a new stimulus is most efficient and in accordance with an individual's capabilities if the input is in a coherent, holistic display (Kahneman, 1973). Attention is directly related to processing capacity, since to allocate more capacity to an input for greater processing really means increasing one's attentiveness to that input (Smith, 1974).

In summary, adequate information processing by the driver is crucial to a smooth flowing traffic corridor. Optimization of the traffic environment by implementation of the SUL must lean heavily upon insuring that drivers perceive and process all the information needed to negotiate a given area. Development of information systems to do just this led to the next body of literature examined.

Driver Information Processing Needs in Various Highway Settings

Ordinarily, information is presented to the driver according to a number of criteria in order to offer a rather complete information cycle (Riemersma, 1979). The cycle includes detection, processing or identifying, decisionmaking, and then acting. This follows from the guidelines previously presented wherein the driver must be alerted to the existence of an upcoming SUL, discover and recognize its rules of operation, and act

accordingly. The existence of the SUL is an aberrant geometric event in the roadway requiring cognitive activity. Literature in the area of positive guidance (Post et al., 1977) more clearly defines the driver's task as he approaches an SUL. Here, the SUL is viewed as one of many possible "condition hazards" ahead which the driver must recognize and effectively negotiate. As stated in the Users' Guide to Positive Guidance, a condition hazard is "any location where the condition of the highway needs to be interpreted by the driver as a cause for extra caution." The occurrence of an SUL system ahead meets this criterion. When such a system is encountered, a sequence of driving events must occur so that effective negotiation of the SUL system is achieved.

A model of these driving events has been developed as part of the concept of decision sight distance and to allow drivers to make a safe and effective maneuver through the system (McGee et al., 1978). The model describes the events that occur in negotiating the SUL (hazard) starting from initial detection of the system to completion of entry-exit activity. The process is briefly described as follows:

1. SUL System Encountered (advance-alert): Visual displays in view
2. SUL System Detected: Driver's eye fixates visual information and "sees" it
3. SUL System Recognized: Eye image translated to the brain as verbal information, existence, rules of use data for SUL
4. Driver Decides on Action: Designates himself as user or non-user of SUL, decides to enter or avoid SUL
5. Driver Begins Motor Response: Initiates entry or avoidance maneuver

6. Driver Completes Maneuver: Through driving in SUL system ensues; return cognitive attention to other inputs.

The process as described is a simple time-additive model, in that all of these events are incremental steps from initial alert to maneuver completion. Successful completion of these steps in safe fashion demands clear, conspicuous presentation of visual information to allow effective decisionmaking in regard to the SUL system. The next section describes the final body of literature providing a basis for development of visual displays.

Guidelines to Effective Visual Display Design

Many years of signing research and operational experience clearly show the importance of standardizing signing and delineation systems (Dietrich & Markowitz, 1972). To date, traffic engineers have had little direction for design of signing and delineation for SULs. The diamond symbol, denoting a restricted lane, was not promulgated as a standard until 1974 (FHWA, 1975). Although the MUTCD (FHWA, 1975) provides some outlines for these diamond-based signs and markings, the wording and symbology are generally not based on direct empirical research evidence. Aspects like contrast, conspicuity, discriminability, and legibility are well understood, and this knowledge is usually well incorporated into traffic manuals (Jenkins & Cole, 1979; Olson & Bernstein, 1979; Ells & Dewar, 1979). Letter height, for example, is specified to accommodate 85% of the driving population with respect to visual acuity (Forbes, 1980). These are properties of the detection and recognition of the sign (and marking) image, however.

Visual information for the SUL usually must interfere with the automatic behaviors of controlling and guiding the vehicle. Cognitive attention to the new input is demanded for processing and proper decisionmaking, until the desired maneuver is complete. Essentially the driver must decide whether he is eligible to be a user or non-user of the SUL, and then act accordingly. This basic decision is contingent upon effective display of the existence, location, and rules of use for the SUL so that adequate detection and processing activities can occur.

Yet perception of the visual information is an active process, dependent upon the mental set and motivation of the individual driver (Riemersma, 1979). Johansson and Rumar (1966) found that the probability of people remembering the traffic sign that they just passed varies greatly with subjective significance of the sign. Thus, in order to be effective, the SUL signing must fulfill more conditions than just the necessary detection and recognition distances (McGee et al., 1978). These depend on lighting conditions, size of letters, placement of signs, use of reflective materials, etc., as mentioned above. The SUL signing must also be understood and the message effect the desired behavior, i.e., entry or non-entry in the indicated lane. This is what some researchers have called the "comprehensibility" of the display (Riemersma, 1979). When the driver has to make logical deductions to determine if a message is relevant for him, i.e., bus/carpool only, additional processing time is required. Also, since the presence of an SUL along the traveled path can be of varying length, the information about its use and location must be given as a total system of information from advance alert to termination, as well as throughout. The system must be such that it follows a quick and easy learning process--suggesting redundant forms, shapes, colors, and symbology; and standardized geographic location. Beyond this, the meanings of these messages must be taught explicitly through media campaigns and educational avenues.

This final section has shown that the effectiveness of the SUL information display is dependent on a large variety of characteristics, beyond the well-studied detection and recognition aspects. Only recently have the concepts underlying comprehensibility and accuracy of message interpretation been approached (Jones, 1972; Ells & Dewar, 1979). Introduction of new and standard signing and delineation systems for SULs requires careful research to empirically consider the wide variety of factors involved.

Summary

Drawing from traffic operational literature as well as theoretical reports discussing human information processing capabilities, a picture emerges pinpointing the state-of-the-art for signing and delineation of SULs. As new SUL facilities have been deployed and evaluated, little attention has been paid to standardized usage of informative signs and markings for each system. The typical history of a given SUL usually involves planning a given operation, dedicating lane(s) for special use deployment, noting operational safety, defining enforcement and user acceptance characteristics, and then reaching a decision point for continued operations or abandonment. Signs and markings used and developed along the way are somewhat of a by-product of the process rather than an integral part of system development. A notable exception was the I-95 high occupancy vehicle lane in Miami where some actual field testing of varying stripe widths and diamond spacings found their effects confounded by enforcement problems (Courage et al., 1977).

In order to develop a systems concept for signs and markings for SULs, the perceptual/theoretical and driving research study literature was examined. The basic tenets on which to develop

driver needs for information in an SUL system, and critical factors to consider in design of signs and markings, were found. This provides the groundwork for Task 2.

Subject by Reference Matrix

The following pages present an alphabetical listing of every document reviewed pertinent to special usage lanes in a matrix format. The matrix consists of a list of the documents on the left side with twenty-eight subject headings in five general areas on the right side. Reading across, left to right for any given document, those subject areas addressed in that document are marked. Thus in a single glance a reader can recognize the subject matter of any listing; or conversely, select a certain subject area of interest and find documents relating to that area.

As stated above, four basic categories define the documents. First are those relating to specific special usage lanes sites and facilities, usually giving their operating characteristics, general performance, and in some reports, descriptions of signing and delineation on these facilities. Second are documents relating to the theoretical principles underlying human perception of information displays, and information processing as related to new and novel systems such as SULs. Third are those documents covering driver information needs in various highway environments. Fourth, specific documents were reveiwed related to signing and delineation technology and covers specific research which provides guidance in designing signing and delineation systems. In addition, a classification of the documents themselves is given so that a reader may know if a particular report is a research study, a general discussion, a status report, etc.

SPECIAL USE LANE LITERATURE SUBJECT MATRIX

	Special Use Lane Inventory									Current Practice & Standard-Signing & Delineation	Human Information Processing		Driver Information Requirements Technique	Signing & Delineation Studies/Design Principles										Type of Document					
	Type of Facility							Operating Characteristics	Performance Evaluation		Signing Related	Theoretical/General		Hardware/Display Types					Vision Variables	Information Coding	Placement	Maintenance	Cost-Effectiveness					
	Freeway	Non-Freeway	Reserved	Non-Reserved	Reversible	Non-Reversible	Contraflow							Static Signs	Dynamic Signs	Paint Markings	Delineators	Signals						Research Study	Bibliography	General Discussion	Status Report	Standard/Official Ruling/Guideline
Adams, 1973												•												•				
Alan M. Voorhees, 1973	•		•		•				•															•				
Alan M. Voorhees, 1973a	•		•		•			•	•															•				
Alexander, King & Warskow, 1970											•		•											•				
Amer. Inst. Graph. Arts, 1974																								•		•		
Anderson & Pederson, 1963														•	•	•				•				•				
Anonymous, 1971	•		•			•	•	•		•																•		
Anonymous, 1972		•	•			•		•	•																		•	
Anonymous, 1973									•																	•		
Anonymous, 1976	•		•				•	•	•																	•		
Anonymous, 1976a	•		•			•			•																	•		
Anonymous, 1977		•		•	•			•	•																		•	
Bakker, 1975								•	•																			
Ball, McGee & Taylor, 1976																•	•			•		•	•		•	•		

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	Type of Facility							Operating Characteristics	Performance Evaluation		Signing Related	Theoretical/General		Hardware/ Display Types																
	Freeway	Non-Freeway	Reserved	Non-Reserved	Reversible	Non-Reversible	Contraflow							Static Signs	Dynamic Signs	Paint Markings	Delineators	Signals	Vision Variables	Information Coding	Placement	Maintenance	Cost-Effectiveness	Research Study	Bibliography	General Discussion	Status Report	Standard/Official Ruling/Guideline	
Banks & Prinzmetal, 1976												•											•	•				
Berger & Hanscom, 1974											•	•	•	•										•				
Bhise & Rockwell, 1972													•	•					•	•				•				
Bigelow-Crain, 1975	•		•				•	•	•					•												•		
Birren, 1977														•					•					•				
Brainard, Campbell & Elkin, 1961														•						•				•				
Brothers, et al, 1975	•		•		•	•	•		•															•				
Calif. Dept. Trans., 1975	•		•			•		•	•																	•		
California, 1976	•		•			•			•																	•		
Calif. Div. Hwy., 1962																•			•			•	•	•				
Capelle, et al, 1972	•		•			•		•	•															•				
Carlow, 1975												•												•				
Carr, 1975		•	•			•	•		•																	•		
Coolkasian, 1974												•												•				
Council & Hunter, 1975									•															•				

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	Type of Facility														Hardware/ Display Types																
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Courage etal, 1977	•		•			•		•	•	•															•			•		
Courage & Michalopoulos, 1976						•			•																•					
Cox, 1975		•	•			•		•	•																•					
Crein, 1975	•		•			•		•	•																		•	•		
Decker, 1961														•					•						•					
DeGreene, 1970												•															•			
Dept. of Trans., 1975	•	•	•	•	•	•	•	•	•																		•			
DeRose, 1966		•		•	•			•	•	•															•					
Dewer & Swenson, 1972														•						•					•					
Dewer, 1973											•			•					•	•					•	•				
Dewar, 1976														•						•					•					
Dewar, Ells & Cooper, 1977											•	•	•	•				•		•	•		•		•					
Didion, 1977	•		•					•	•																		•			
Dietrich & Markowitz, 1972											•														•					
Dudek & Jones, 1971													•		•					•					•					
Dudek, et al, 1971a											•																			

SPECIAL USE LANE LITERATURE SUBJECT MATRIX

	Special Use Lane Inventory: Type of Facility: Freeway	Non-Freeway	Reserved	Non-Reserved	Reversible	Non-Reversible	Contraflow	Special Use Lane Inventory: Operating Characteristics	Special Use Lane Inventory: Performance Evaluation	Current Practice & Standard-Signing & Delineation	Human Information Processing: Signing Related	Human Information Processing: Theoretical/General	Driver Information Requirements Technique	Signing & Delineation Studies/Design Principles: Hardware/Display Types: Static Signs	Dynamic Signs	Paint Markings	Delineators	Signals	Vision Variables	Information Coding	Placement	Maintenance	Cost-Effectiveness	Type of Document: Research Study	Bibliography	General Discussion	Status Report	Standard/Official Ruling/Guideline
Dudek, 1975											•		•	•	•			•					•		•			
Dupree & Pratt, 1973	•	•	•		•	•	•		•	•														•				
Dupree & Pratt, 1973a	•	•	•		•	•	•	•	•	•														•			•	
Eberhard, 1969													•											•				
Eberhard & Berger, 1972														•					•					•				
Ebersole, 1975	•	•	•					•	•															•				
Ebersole, 1976	•	•	•					•	•																•			
Ells & Dewer, 1979													•	•				•	•					•				
Erdman & Panuske, 1976		•	•		•			•	•															•				
European Conf., 1974										•								•							•			
Everall, 1972	•		•					•																	•	•		
Falls of the Ohio Met., 1972		•	•				•	•	•																•			
FHWA, 1974	•		•		•	•	•	•																	•			
FHWA, 1975										•																	•	
FHWA, 1975a										•																	•	

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FHWA, 1976										•																		•
FHWA, 1976a	•	•	•		•		•	•	•	•																	•	
Florida Dot, 1977		•	•			•		•	•																•			
Forbes, et al, 1960											•													•				
Forbes, Snyder & Pain, 1964											•			•					•					•	•			
Forbes, et al, 1967											•			•					•		•			•				
Forbes, et al, 1967a											•			•										•				
Forbes, et al, 1968														•					•					•				
Forbes, et al, 1968a														•					•					•				
Forbes, et al, 1974														•					•					•				
Forbes, 1976											•													•				
Forbes, 1976a														•					•					•				
Foxen, 1975		•				•		•	•															•				
Gallagher, 1975	•		•			•			•																	•		

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Gallagher, 1975a	•		•			•			•																	•		
Gallagher, 1975b	•		•			•		•	•																	•		
Goodman, J.M., 1970	•		•		•	•	•	•																				
Goodman, L., 1972	•		•			•			•															•				
Goodwin, 1976													•								•			•		•		
Gordon, 1972														•						•				•				
Gordon, 1976					•										•					•				•				
Graham & Volk, 1972														•						•				•				
Grossman, 1976												•														•		
Gwynn & Seifert, 1968																•				•				•				
Hanscom & Berger, 1976														•						•				•				
Hanson & Woltman, 1967														•					•		•			•				
Heaton, et al, 1976									•																		•	
Heron & Adam, 1974												•												•				

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Holder, 1971											•			•					•		•				•	•		
Horn, 1974		•	•			•		•	•																	•		
Horowitz & Kuhrtz, 1974			•						•																	•		
Hostetter, 1976														•					•	•				•	•			
ITE, 1977										•																		•
Jenkins & Cole, 1979													•	•					•	•				•				
Johanasson & Rumar, 1966											•		•	•					•	•	•	•		•				
Johnston & Cole, 1976											•															•		
Jones, 1972													•	•	•	•	•	•	•	•	•	•	•	•				
Kahneman, 1973												•	•	•	•	•										•		
King & Lunenfeld, 1971											•	•														•		
King & Lunenfeld, 1972										•				•						•					•			
King & Tierney, 1970													•	•					•	•				•	•			
King & Tierney, 1971														•						•				•				
King, 1975														•				•		•				•				
Knapp, et al, 1973											•													•				
Kolsrud, 1972														•						•			•	•		•		
Ladan, Heron & Nelson, 1974												•												•				

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	Type of Facility													Hardware/ Display Types																
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LaPlante, 1975		•	•			•	•	•	•																		•		
Lathrop, 1972					•				•																		•	•	•
LEA Transit Compendium, 1977	•		•	•		•	•	•	•																	•			
Levinson, et al, 1973	•		•		•	•	•	•	•																			•	
Levinson & Sanders, 1974	•		•			•	•																		•				
Levinson, et al, 1975	•		•		•	•	•	•																				•	
Levinson (active)	•		•			•		•																		•			
Lewis, 1975												•													•				
Link, D., 1973	•		•		•	•		•	•																	•			
Link, 1975	•		•				•		•																	•			
Link, 1975a	•		•			•			•																	•			
Lipowski, 1975												•														•			
Lopatin, 1976	•		•		•		•	•	•																	•		•	
Lunenfeld & Alexander, 1976											•			•											•				

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McKnight & Adams, 1970													•											•				
McQuean, et al, 1974	•		•		•				•																		•	
McQuean, et al, 1975	•		•		•				•																		•	
Mace, Hostetter & Sequin, 1967											•		•	•					•	•				•	•			
Mark, Ho & Papacostas, 1976	•		•			•		•	•	•														•		•	•	
Mast & Ballas, 1976											•													•				
Mast, et al, 1976											•															•		
May & Westland, 1979																												
Mihal & Barrett, 1976												•																
Miller, 1976																•	•		•		•	•	•	•		•		
Miller & Deuser, 1976			•																					•				
Miller & Deuser, 1978	•	•	•	•	•	•	•	•	•																	•	•	
Miller et al , 1979	•	•	•				•	•	•																	•	•	
Missouri, n.d.		•		•	•				•																	•	•	
Morin, D.A., 1974									•																	•		
Morin, 1975			•																							•		
Neval Under. Systems, 1976								•																		•		

SPECIAL USE LANE LITERATURE SUBJECT MATRIX

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	Type of Facility							Operating Characteristics	Performance Evaluation					Hardware/ Display Types														
	Freeway	Non-Freeway	Reserved	Non-Reserved	Reversible	Non-Reversible	Contraflow				Signing Related	Theoretical/General		Static Signs	Dynamic Signs	Paint Markings	Delineators	Signals	Vision Variables	Information Coding	Placement	Maintenance	Cost-Effectiveness	Research Study	Bibliography	General Discussion	Status Report	Standard/Official Ruling/Guideline
Neisser & Beckien, 1975												•											•				
Newman, 1976	•		•			•	•	•																		•	
Odescalchi, 1960														•					•				•				
Organization for Econ., 1975																•	•		•			•	•		•		
Oren, 1976								•																•				
Oregon DOT	•		•			•		•	•																	•		
Oregon State, 1966														•		•	•			•			•					
Owens, 1977	•	•	•			•	•	•		•														•		•		
Peters, n.d.										•														•				•
Peters, et al, 1975											•													•				
Peters, J.I., 1976													•											•				
Pigman, Agent & Rizenbergs, 1975																•			•			•	•	•				
Pomerantz & Schwaltzberg, 1975												•												•				
Post, et al, 1977												•	•															•
Program Committee, 1977								•	•																	•		

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Public Technology, 1977	•	•	•																									•
Public Technology, 1977a	•	•	•																									•
Public Technology, 1977b	•	•	•							•																		•
Riemersma, 1979											•		•	•			•	•	•	•	•	•	•	•		•		
Roberts, Rielly, & Jagennath, 1975														•						•				•				
Roberts & Klipple, 1976											•													•				
Robertson, H.D., et al, 1975											•	•												•				
Robertson, 1976														•					•			•	•	•				
Rock, Schauer & Halper, 1976												•												•				
Rose & Hinds, 1976	•		•				•		•																	•		
Roth & DeRose, 1965														•		•	•			•				•				
Rothenberg, 1977	•	•	•			•		•	•																	•		
Rotton, 1973												•												•				
Rowan, 1963														•		•	•			•				•				
San-Jose – Palo Alto, 1972	•	•	•			•		•																		•		

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Schwant, Hillyard & Galambos, 1976						•		•	•	•		•												•				
Simkowitz, 1978	•		•			•		•	•	•																		
Smith, 1974												•														•		
Starbuck, J.C., 1976	•	•	•	•	•	•	•	•		•															•			
Stockton, et al, 1975											•													•				
Streufert, 1973												•												•				
Taylor, n.d.																•				•				•				
Taylor & Hubball, 1967																•			•	•				•				
Taylor, 1968																•				•				•				
Taylor, 1970	•		•		•				•															•				
Taylor & Datta, 1971																•			•					•				
Taylor, et al, 1972													•			•	•		•	•			•	•	•			
Taylor, at al, 1974		•	•			•		•	•																		•	
Taylor & McGee, 1973													•											•				
Tiemann, 1976			•		•	•																				•		
Tipton, W.E., 1969		•		•	•			•	•	•																•		

CHAPTER 3

DEVELOPMENT OF INFORMATION REQUIREMENTS FOR SPECIAL USAGE LANES

Information requirements of drivers have been studied and discussed in the literature for many years (e.g., King & Lunenfeld, 1971). However, attention has been focused on standard roadway operations, with the unusual or unique situation such as special usage lanes (SULs) minimally touched. Moreover, even though the information requirements for these situations have not been treated, there is an abundance of data on the information processing and psychomotor tasks necessary to negotiate special usage lanes, primarily because no new tasks are required. Once appropriate information is processed by the driver, similar task requirements (e.g., lateral and vertical alignment of the vehicle) found on a standard arterial street or freeway are imposed in the SUL situation. The state-of-the-art for information processing and task requirements has been described by Berger and Hanscom (1974) and King and Lunenfeld (1971).

While task requirements may be typical, SULs have characteristics which suggest that certain aspects of human information processing must be emphasized in considering SUL information requirements. The SUL characteristics to be considered are:

- SULs are relatively rare.
- SUL signing and delineation is not standardized.
- Drivers who frequent SULs integrate the information into their expectancies.
- A small, steady, and continuous number of travelers come into contact with unfamiliar SULs.

These characteristics indicate that a driver who is familiar with a particular SUL may neither understand nor have an adequate

expectancy concerning an SUL encountered in an unfamiliar part of the country. While this category of drivers is very small in number compared to the volume of peak hour drivers regularly interfacing with an SUL, it represents a group most likely to engage in unsafe driving behaviors (e.g., gore weave, multiple lane changes, slowing or stopping), if information requirements are not met (Hanscom & Berger, 1976).

Therefore, there was a need to develop the information requirements of drivers in dealing with SULs. The process followed in arriving at these requirements included:

1. Inventory and categorization of SULs

2. On-site visit to SULs of each category to acquire:
   - drive-through experience and movies of each facility
   - accident and operational data/information from traffic engineers and transit and enforcement personnel
   - operational difficulties/successes from time-lapse filming and/or personal observation of the SUL while functioning
   - photos of existing signing

3. Review of relevant literature (from Chapter 2)

4. Development of information requirements for each category of SUL

5. Identification of SUL categories with unique information requirements.

Inventory and Categorization of SULs

Review of the literature demonstrated that special usage lanes exist in a wide variety of configurations and functions. Information systems could not be developed for every case, so some means of classifying these facilities had to be established. This classification scheme served as a basis for determining site visits and the number of information systems to be developed.

Classification of Special Usage Lanes

From an examination of the literature concerning special usage lanes (Rothenberg, 1977; Wilbur Smith & Associates, 1975; Working Party on Bus Priority Systems, 1976), five parameters appeared to adequately characterize existing special usage lanes. They were:

- Arterial or freeway
- Reversible, contra-flow, or nonreversible
- Reserved or nonreserved
- Physically separated or no physical separation
- Right lane, left lane, or median lane.

Table 2 provides definitions for each of these parameters, which were then placed in a matrix format as shown in Figure 1.

Special Usage Lane Inventory

As special usage lane facilities were identified, they were placed in the appropriate cell of the classification matrix. Because there is continuing change in the number and type of SULs due to modifications, start-up of new facilities, or discontinuance of SUL operations, the inventory created at the beginning of the project is out of date by this writing. Therefore, percentages have been entered in the cells of Figure 1 as an indication of

Table 2

Definition of Special Usage Lane Parameters

Arterial	Standard MUTCD definition.
Freeway	A limited access facility.
Reversible	Any lane(s) which change direction of traffic flow.
Contra-flow	Any lane going in a direction opposite the generally accepted and signed traffic flow.
Nonreversible	Lanes permanently carrying traffic in a given direction.
Reserved	Some category of user allowed on the main roadway is not allowed to use the special usage lane.
Nonreserved	Any user of the main roadway can also use the special usage lane.*
Physically Separated	A permanent and substantial barrier, e.g., median strip, guard rail, New Jersey barrier, separates the special usage lane from other traffic lanes.
No Physical Separation	Temporary (cones, posts) or no barriers separate the special usage lane from mainstream traffic.
Right Lane	Curb or outside shoulder lane.
Left Lane	The lane closest to the median barrier or center stripe.
Median Lane	The middle lane of an odd number of lanes, e.g., lane three in a five-lane roadway.

*There are many cases where trucks are permitted in the right lane only. These are considered nonreserved facilities for purposes of this project.

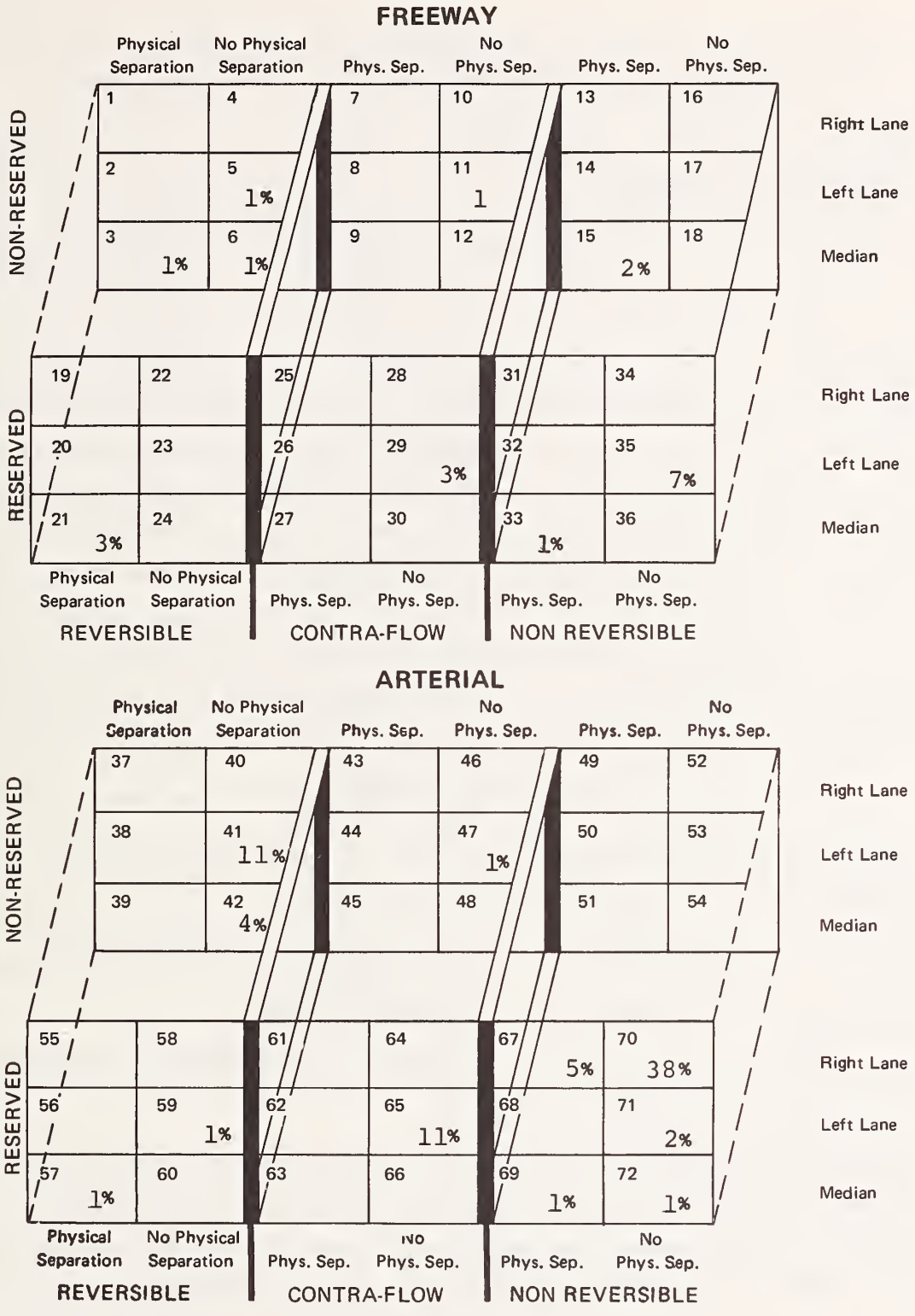


Figure 1. Categorization of special usage lanes (in percent of total number of SULs).

the general deployment rate for different SUL types. The entire inventory is fully described in a earlier published report (Pain et al., 1977).

Under the Figure 1 matrix, a recent innovation in special use lanes is noted: the special use shoulder. Traffic engineers hard pressed to find financial, political, or community support for new facilities are called on to increase capacity or encourage use of high occupancy vehicles. In response, the shoulder as a lane for buses and/or carpools during peak periods is being tried and use of the shoulder as a nonreserved lane during certain hours is being tested. Similar capacity problems, coupled with financial constraints, exist throughout the country. If shoulder use is successful, widespread application is possible. While only a small number of these currently exist, this type of special usage lane was considered in this project because there are driver information difficulties associated with shoulder use.

On-Site Visits

Facilities were chosen from each matrix cell for an on-site visit using the following criteria:

- the SUL represented a cell in the inventory matrix,
- the SUL was currently operating, and
- the SUL had potential application in other geographic areas.

In three cases--cells 6, 47, and 57--the criteria were not satisfied; a special trip to the facility was not justified and no visit was made. In several other cases where the criteria were not met, the facility was in the same location as another target site; so a visit was efficiently accomplished. The specific facilities visited are noted in Table 3.

Table 3
SUL Facilities Visited

FREEWAY

MATRIX CELL NUMBER	CITY	FACILITY NAME
3	SEATTLE	I-5
5	CHICAGO	LAKE SHORE DRIVE
11	CHICAGO	LAKE SHORE DRIVE
15	CHICAGO	DAN RYAN I-90/94
21	CHICAGO	J.F.K. EXPRESSWAY I-90/94
	WASHINGTON, D.C.	SHIRLEY EXPRESSWAY I-395
29	NEW YORK	I-495– LINCOLN TUNNEL
	NEW YORK	LONG ISLAND EXPRESSWAY
	SAN FRANCISCO	U.S. 101
33	LOS ANGLES	SAN BERNADINO BUSWAY
34	SAN DIEGO	RT. 163
35	PORTLAND	BANFIELD EXPRESSWAY
	SAN FRANCISCO	U.S. 101
	LOS ANGELES	SAN BERNADINO BUSWAY
	SAN FRANCISCO	I-280
SHOULDER	BROOKLYN	BROOKLYN-QUEENS EXPRESSWAY
	SEATTLE	RT. 520

ATRERIAL

MATRIX CELL NUMBER	CITY	FACILITY NAME
41	WASHINGTON, D.C.	CONNECTICUT AVE. M STREET
	ARLINGTON, VA	WILSON BLVD. COLUMBIA PIKE
	SEATTLE	TEMP. I-90
	HARRISBURG, PA.	MARKET ST. BRIDGE
	CHICAGO	N. SHERIDAN RD. HOLLYWOOD AVE.
42	WASHINGTON, D.C.	16TH ST. CANAL RD. GEORGIA AVE.
	SILVER SPRING, MD.	U.S. 29
59	HONOLULU	KALANIANAOLE HWY.
65	CHICAGO	CANAL RD.
	HARRISBURG, PA	MARKET ST.
	LOS ANGELES	SPRING ST.
67	CHICAGO	ENGLEWOOD SHOPPING CENTER
	PORTLAND, ORE.	SHOPPING DISTRICT
69	SAN FRANCISCO	POWELL ST.
70	WASHINGTON, D.C.	CONNECTICUT AVE. 16TH ST. 14TH. ST.
	ARLINGTON, VA.	WILSON BLVD.
	BALTIMORE	YORK RD.
	DENVER	LINCOLN-BROADWAY 16TH AND 17TH STs.
	SAN FRANCISCO	EIGHT DIFFERENT STREETS
	PHILADELPHIA	
71	HONOLULU	KALANIANAOLE HWY.
72	CHICAGO	WASHINGTON ST.
SHOULDER	SEATTLE	RT. 522

At each site the following activities took place:

- Meetings were held with local transit management and city, district, state, or regional traffic engineers.
- Driver's eye view (drive-through) films of each site and still photographs of signing/delineation were taken.
- Operations were observed to identify problems.

Other types of data were obtained only where appropriate or available, including:

- Summaries of accident records. Where a government body specifically performed an accident study for an SUL, data were available; however, this was the exception. In most cities, accident data were available for a roadway, but there was no way of separating accidents on or involving the SUL from non-SUL related accidents.
- Time-lapse filming from vantage points overlooking the special usage lane. At sites with no overlooks, filming was not attempted.
- Line or engineering drawings of the facility and/or signing. Appropriate drawings were not available for most of the older sites.

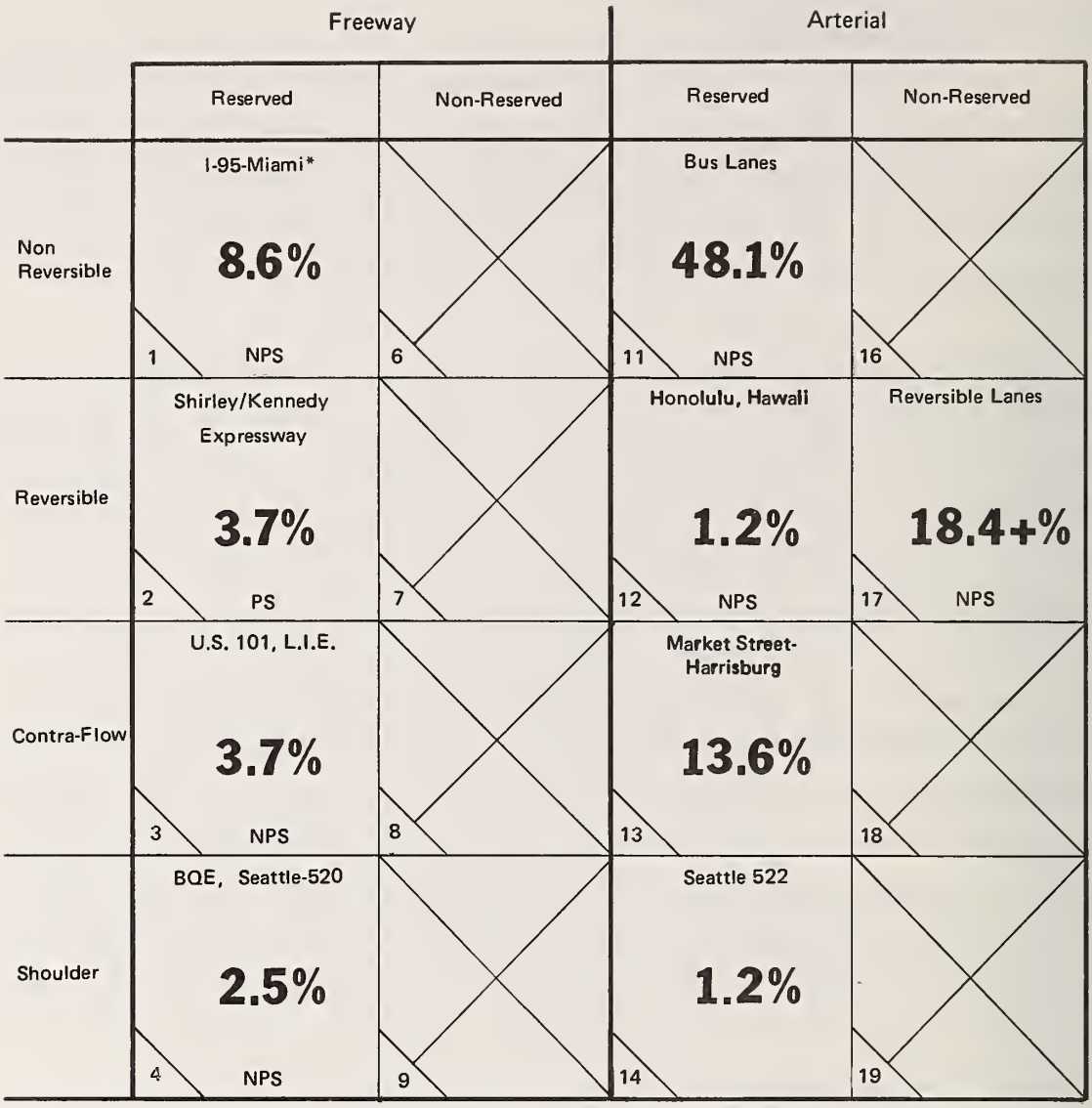
The information from these site visits was used in two ways. After information requirements were developed, they were compared with the signing and delineation existing for each class of SULs. This comparison was fully documented in Appendix I of Pain et al. (1978). A second type of data obtained from the on-site visits was identification of SUL problems possibly related to the signing and delineation systems or deficiencies therein.

Problem Areas Identified During SUL Site Visits

One objective of the site visits was to identify problems encountered by drivers as they negotiate a given SUL environment. After these problems were discovered, the next consideration was to determine if any of these problems were related to deficiencies or inadequacies in the signing and delineation of the system.

Discovering problem areas related to SULs was a problem in itself, for at least two reasons. First, accident data obtained from various sites generally did not have the coded information to differentiate the SUL from the regular roadway. Second, the majority of drivers observed on SUL facilities appear to be seasoned users of these roadways, generally using them for the a.m. and p.m. work trips. They are thus able to negotiate them well, in spite of operational and informational deficiencies. A case in point was observed on a reversible lane operation in Washington, D.C. Changeable message signs were malfunctioning along the facility, alternately directing drivers to use two lanes or three lanes--they were actually permitted to use three. Drivers were consistently using three lanes, regardless of the information display, indicating that the rules of this system were well known and little attention was being given to the sign.

In spite of the above-mentioned impedances to detection of problem areas, certain observations about SUL problem areas may be made. Some of these are cell specific (cells here refer to the matrix shown in Figure 2); that is, related to facilities of one type only. These are listed and summarized in Table 4. Other problems observed are more general in nature. These are listed in Table 5.



PS = Physically Separated.
NPS = Not Physically Separated.
* = At least one example or descriptor is listed for each cell.

Figure 2. Special usage lane categories requiring signing and delineation system development.

Table 4

SUL Problem Areas - Cell Specific

Cells	Related to Signing and Delineation		
	Yes	Some	No
Cell # 1. Freeway, Reserved/Non-reversible			
• No shoulder to allow enforcement officials to ticket violators of the SUL - consequently violations high			✓
• Often the SUL is separated only by a solid white line. Drivers mistake this for a shoulder, use it for breakdowns, therefore can incur collision with HOV vehicles that come along	✓		
Cell # 2. Freeway, Reserved/Reversible			
• Forgiving approach lane must be accompanied by strong advance and entrance information displays; usually no exit from SUL once on it.		✓	
Cell # 3. Freeway, Reserved/Contra-flow			
• Violators cannot be apprehended within the lane			✓
• Cones used require elaborate set-up and manhours	✓		
• Lane markings do not reflect SUL characteristics since the lane must return to normal use	✓		
Cell # 4. Freeway, Reserved/Shoulder			
• Weave area near entrance and egress ramps not marked to give right-of-way priorities to HOVS	✓		
• Information requirement to tell drivers that shoulder can be used for breakdown during off peak or not is not addressed	✓		
• Closure and merge information for users is deficient	✓		
• Some shoulders have inadequate lane width for buses - creates operational flow friction			✓
Cell # 11. Arterial, Reserved/Non-reversible (HOV Lanes)			
• Definition of right turning vehicles needed	✓		
• Consistency needed in use of diamond symbol between signs and pavement	✓		
• Parking violations rampant in downtown sites where bus lane reverts to parking stalls in off-peak		✓	✓

Table 5

SUL Problem Areas–General

- Information must be given in an already visually cluttered environment.
- The diamond symbol as used connotes no consistent meaning.
- Display inconsistencies occur when two SULS are found on the same facility.
- Many SULS are superimposed on other facilities and only operate during certain hours. Thus SUL delineation is often absent.
- Use of traffic cones as delineators requires manhours and careful placement.
- Public acceptance of SULS is variable and related to regional and attitudinal differences regarding carpooling.
- Signing was effective in many areas only when combined with adequate and consistent enforcement.

Information Requirements Analysis Procedure

In essence, determining information requirements is a process of melding SUL site data, human engineering data, highway operational realities, and expert judgment. The first two items have been discussed. The remaining items were provided via a panel of human engineering and traffic engineering experts.* This panel convened for three days. During the meeting, every site within each classification matrix cell was reviewed. All photo logs, interviews, observations, and other data were presented and discussed. Various problems or difficulties at each site were noted. A preliminary set of information requirements had been prepared for each cell prior to the meeting. Table 6 illustrates and explains the conceptual outline used in preparing information requirements. These were critiqued, modified, and then compared to each site to assure that no information requirement was neglected. At the same time, other possible situations were hypothesized and the information requirements compared to determine adequacy. The product of this activity was a set of information requirements covering every cell with an entry in Figure 1. These information requirements were presented in Appendix I of Pain et al. (1978). These were not the final information requirements; the requirements synthesis still had to be performed.

Once the information requirements were specified, the panel compared requirements across cells to determine unique and common information elements. In many cases, one cell had a simpler version of the information requirements found in another cell.

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*Panel members included (in alphabetical order) F.R. Hanscom, R.S. Hostetter, B.G. Knapp, D.J. Mace, H. McGee, R.F. Pain, and R.G. Petzold.

Table 6

Conceptual Outline Used in Establishing Information Requirements

	Existence	Rules of Use	Location	Motivation
Approach				
Entrance				
Through				
Exit				

Definitions

Approach	Roadway prior to physical entrance or beginning of a special use lane.
Entrance	The physical beginning (reverse lane starts, gore area at express lane junction) of a special use lane.
Through	The special use roadway running from the entrance to the exit.
Exit	The point of leaving the special use lane either through cessation of special operation (e.g., reversible lane) or merge into regular roadway.
Existence	Information telling the driver that a special use lane exists on the roadway.
Rules of Use	Information about who can use the lane, when to use it, and operating characteristics, e.g., speed limit, headlights on, no passing.
Location	Information giving location of the special use lane, e.g., left exit, median lane guidance information about the lane and navigational information, e.g., next exit.
Motivation	Information relating to consequences/benefits of lane use or nonuse, enforcement, or how to become eligible to use the special use lane.

For example, express lanes with no vehicle type restrictions have the same information requirements as express lanes reserved for cars only, except that no restriction information need be conveyed. The result of this analysis was a set of consolidated information requirements, presented in Table 7, and a corresponding consolidated classification matrix. Figure 2 is the synthesized matrix and shows the nine SUL categories requiring separate sets of information requirements. The rationale used for pooling information requirements among cells is given in Appendix II of Pain et al. (1978). The information requirements for all SULs in the original inventory matrix can be met using the full or some subset of the information requirements for one of the nine cells in the new matrix (Figure 2).

Note that the category "shoulder" has been added to the collapsed matrix (Figure 2) and information requirements presented for this type of facility (Table 7). In discussions with state and local traffic engineers, the problem of increasing capacity at minimum cost while avoiding new construction is very real. Using shoulders for added capacity appears to be a workable technique that will become increasingly popular. Therefore, appropriate signing and delineation would be available for use by the transportation planning community.

The final set of information requirements appears deceptively simple. The requirements statements are brief and relatively general in nature. This was necessary to achieve the flexibility to cover the wide variety of site characteristics and types of operations found in existing and anticipated special usage lanes. Also, more specific requirements would imply a particular signing or delineation technique, and this was not the purpose of the information requirements. Rather, signing and delineation systems would be created in response to the information requirements.

Table 7

Information Requirements – Consolidated Classification Matrix

CELL NO. 1. FREEWAY, NON-REVERSIBLE/RESERVED

Approach
- Existence
- Location
- Type of Restriction
- Egress Limitation
- Type of Operation

Entrance
- Existence
- Location (Lane Divergences)
- Type of Restriction
- Egress Limitations

Through
- Standard Exit or Entrance Signing
- Lane Definition

Exit
- Standard Exit or Merge Signing
- Establish Priority for Yield or Right-of-Way if applicable

CELL NO. 2. FREEWAY, REVERSIBLE/RESERVED

Approach
- Existence
- Vehicle Restrictions
- Time of Operation
- Location
- Notice of Enforcement

Entrance
- Vehicle Restriction
- Time of Operation
- Location

Through
- Repeat Same as Entrance with Standard Exit and Entrance Signing

Exit
- End of Facility
- Standard Exit Information

CELL NO. 3. FREEWAY, CONTRA-FLOW/REVERSIBLE

Approach (with flow)
- Existence
- Time of Operation
- Vehicle Restriction
- Rules of Use
- Location

Approach (against flow)
- Existence
- Location

Table 7 (Cont.)

Information Requirements – Consolidated Classification Matrix

Entrance
- Location
- Vehicle Restriction
- Time of Operation
- Rules of Use

Entrance
- Location
- Lane closure

Through
- Location
- Rules of Use
- Time of Operation

Through
- Lane edge definition
- Existence of two-way traffic

Exit
- End of Existence
- Exit Procedure

Exit
- Cessation of opposing traffic
- Lane availability

CELL NO. 4. FREEWAY, SHOULDER/RESERVED

Approach
- Existence
- Location
- Type of Restriction
- Time of Operation

Entrance
- Location
- Type of Restriction
- Time of Operation

Through (and crossing/merging traffic)
- Location
- Type of Restriction
- Time of Operation

} Repeat on entrance ramps

- Use SUL for exit lane

Exit
- End of Facility
- How to Exit

CELL NO. 11. ARTERIAL, NON-REVERSIBLE/RESERVED

Approach
- Existence
- Type of Vehicle Restrictions
- Location
- Time of Operation
- Rules of Use

Table 7 (Cont.)

Information Requirements – Consolidated Classification Matrix

Entrance/Through
- Vehicle Restrictions
- Time of Operation
- Location
- Rules of Use

Exit
- End of Facility
- How to Exit

CELL NO. 12. ARTERIAL, REVERSIBLE/RESERVED

Approach
- Existence

Entrance
- Time of Operation
- Vehicle Restrictions
- Location

Through
- Time of Operation
- Vehicle Restrictions
- Location
- Side Street Traffic: Turning Prohibitions

Exit
- End of Facility

CELL NO. 13. ARTERIAL, CONTRA-FLOW/RESERVED

Approach
- Existence

Entrance
- Location
- Vehicle Restriction
- Rules of Use (Bus Driver Training)

Through
- Location
- Existence of Traffic in Opposite Direction
- Side Street Traffic: Turning Prohibitions
- Pedestrians: Mandate Look Both Ways

Exit
- End of Facility

Table 7 (Cont.)

Information Requirements – Consolidated Classification Matrix

CELL NO. 14. ARTERIAL, SHOULDER/RESERVED

Same information requirements as Cell No. 11 except increase conflicts with side street traffic from right since sight distance cut off.

CELL NO. 17. ARTERIAL, REVERSIBLE/NON-RESERVED

Approach

- Existence (Direction)
- Time of Operation

Entrance/Through

- Direction
- Time of Operation
- Side Street Traffic: Existence of Reversible Lane Turning Prohibition

Exit

- None Except Merge Information if applicable

CHAPTER 4

DEVELOPMENT OF INFORMATION SYSTEM ALTERNATIVES FOR SPECIAL USAGE LANES

With the site visits and information requirements for special usage lanes completed, possible ways to meet those information requirements could be developed. The expert panel described in Chapter 3 reviewed the information requirements for each cell (as shown earlier in Figure 2), considering existing methods (e.g., MUTCD, operating facilities), relevant human factors principles (e.g., primacy, spreading, closure), and operational realities (e.g., cost, state-of-the-art in signing, visual clutter). They then created alternative signing and delineation systems.

The product of this activity was a series of information systems. They were, however, tentative and generally incomplete because many questions arose about specific signing or delineation components which, until answered, made final design decisions arbitrary or impossible. Specific preliminary signing system designs are discussed cell by cell (cells refer to Figure 2) in Appendix A of this volume.

SUL Sign Design Concepts and Assumptions

The information presented on the Appendix A signs was organized according to the primacy concept (King & Lunenfeld, 1971; Post et al., 1977). Analyzing the driver's tasks in approaching an SUL, the decisions to be made come in the sequence illustrated in Figure 3.

Most efficient driver performance should result when the SUL signs present information so the above decisions can be made sequentially. This analysis was the basis for establishing information primacy on the approach to the SUL.

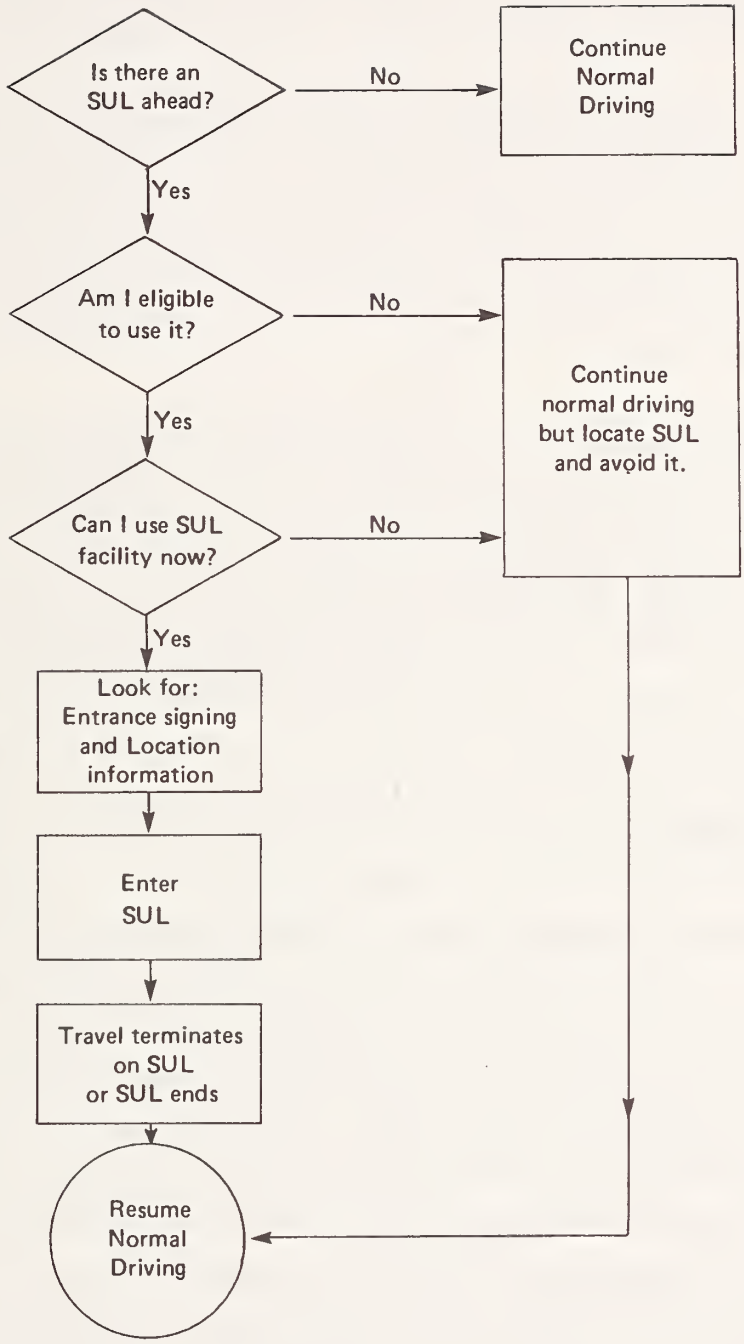

Figure 3. Driver decisionmaking paradigm upon encountering SUL.

At the entrance to the SUL, a diagrammatic indication of location plus delineation is expected to provide the highest primacy information: how to get on or avoid the SUL.

Another type of information that conceivably could be important is destination information. On a non-physically separated facility, this is of minimal importance since all entrances/exits are available to the driver. Only on physically separated SUL facilities must destination information be provided during the approach to the SUL.

During the course of a restricted lane there may be several entrances and exits from the regular lanes. Guide signing, installed according to MUTCD standards (FHWA, 1975), should be sufficient to allow SUL users to move over to the exit lanes. There does not appear to be a need for additional SUL signing. Because vehicles may be entering the roadway at several points, there is a need to provide the SUL location and rules of use information such that the non-eligible drivers will not wander into the restricted lane.

A particular problem with the restricted concurrent flow SUL is continuous definition of the lane so that drivers will be continually aware of the lane's existence. A lane that is restricted 24 hours per day only posseses the problem of type of delineation scheme to put down. The lane with a part-day restriction presents the problem of any delineation treatment: becoming meaningless because it is useless and inaccurate information when lane restrictions are not in force. Standard striping schemes are less than ideal since the dashed white conveys no information about the restriction, and a solid white stripe implies one side of the lane is a shoulder. At least two fatal accidents on one facility were directly attributed to

confusion over the meaning of the solid white line; subsequent evaluation indicated that a dashed white line is just as effective but safer (Courage et al., 1977). A diamond presented in the middle of the lane does not provide continuous information, nor does it provide lane edge definition. Because of these various problems, a new delineation treatment must be developed. The design goal for delineation is to create a scheme that will provide lane edge definition and lane restriction notification continuously. This development required laboratory study, which is discussed in Chapter 5.

At the end of a restricted lane, one of two situations can occur: Either the diamond lane reverts back to a normal lane, or the diamond lane is dropped, i.e., traffic merges into the normal lanes. Except for a sign indicating that the diamond lane ends, all other information is adequately provided by existing standards on lane drops and adds (Goodwin, 1976).

Diamond Symbols

One question of considerable impact to SUL signing concerns the use of a symbol to designate that a lane is restricted in some way. The diamond was approved as a standard symbol for this purpose in 1974 (FHWA, 1975), but its effectiveness is generally unknown. One questionnaire study (Courage et al., 1977) on the meaning of the symbol indicated that the diamond has no inherent meaning relative to highways and very few people had learned the meaning of this symbol. This finding alone would suggest a need to create a new symbol with an obvious meaning. However, from the on-site visits it became clear that the western portion of the country is steeped in the use of the diamond symbol; the symbol is used on a few scattered facilities in the eastern part of the country; and it is almost unknown in the midwest.

The diamond symbol is apparently benign if not understood. That is, it does not elicit a hazardous driver behavior, but when understood, has a meaning not confused with other symbols. Changing the diamond symbol could involve a considerable investment in economics and time--installing new signs, removing diamond symbols from pavement, installing a new symbol on signs, and a massive unlearning the old symbol/learning the new symbol campaign in eastern and western states. The probability of creating a new symbol that is effective and inherently meaningful enough to justify the cost and confusion of a transition appeared highly unlikely based on initial design attempts. Therefore, the diamond symbol will be retained as the symbol indicating some type of lane restriction or prohibition.

Contra-Flow Lanes

Several assumptions that impact on the signing and delineation systems of contra-flow lanes should be noted. First, only buses currently use contra-flow lanes. While there has been discussion of allowing a wider user population, the assumption was made that only registered or permitted van pools might become qualified users in the future. Drivers of such vehicles can be given specific instructions on the use of the contra-flow lane at the time of registration and at renewal times.

Second, because contra-flow lanes are intended for designated drivers only and the hazard associated with errant drivers unwittingly entering a contra-flow lane appears high, this type of SUL should be relatively obscure. On-site observations at one location found two drivers going into and continuing through, one driver entering and backing out, and several drivers swerving to avoid entering the contra-flow lane; this within a 30-minute filming session.

Third, consideration has been given to not using tubes (post cones) to continuously separate the contra-flow from opposing traffic. Regardless of how powerful the signing used, there is a need for continuous delineation of the opposing traffic lanes. This delineation must be obvious and present when contra-flow is operating, and should not be present during concurrent flow operation. This is important in maintaining the credibility of the delineation treatment. If the treatment is always present but is applicable only part of the time, it will tend to be ignored. Therefore, some form of changeable delineation system is required. While placement and removal of tubes is expensive, other alternatives, e.g., barricades rising out of the pavement, are far more expensive.

Finally, the use of a barrier lane depends on the possibility of drivers straying into the opposing traffic lane. Roadway geometrics apparently affect such probabilities. Where extensive curvature is encountered in a contra-flow lane, a barrier lane appears advisable. Steep up- or downgrades subject to considerable icing or snow might also be candidates for barrier lane operation. Very long stretches of contra-flow, where a break-down, emergency, or stopping lane is deemed necessary, may require use of a barrier lane when shoulder space is unavailable. Relatively straight sections of contra-flow can be operated without a barrier lane with no apparent impact on safety. In general, the accident record of freeway contra-flow lanes is better than most other HOV facility operations (Miller et al., 1979).

Delineation at the gore or entrance of the contra-flow lane, whether through painting, movable cones/Type II barricades, or other movable barriers, must not lure drivers into the SUL. Geometric design is also an important factor in a relatively obscure entrance. Normal traffic should clearly flow past the

entrance, not have to avoid the entrance. Delineation should positively guide the driver by the contra-flow lane entrance. (However, some delineation must be given the contra-flow users to show them where to enter the lane.)

SUL Signing Questions and Problems

Even after completing the literature review, on-site visits, information and task requirements analysis, and initial information systems designs, a number of issues were not resolved. They are:

1. Is the word "restricted" the best verbal definition of the diamond symbol? Perhaps words such as "prohibited" or "special use" would more clearly convey the meaning intended by the diamond.

2. The verbal designations for buses, carpools, taxis, and vanpools take considerable space, especially when several are used on one facility. Symbols may be recognized faster, with equal accuracy, and result in more economical sign costs. Two questions arise: Do symbols adequately convey the needed information? Which symbol is sufficiently legible and meaningful?

3. Carpools are defined variously on SULs, ranging from two to four persons per car. Several different methods of presenting such defining information need to be studied further. Possible techniques include: a car symbol with the number of body silhouettes representing the required number of people constituting a carpool; a similar car symbol with a digital number; a digital number inside the diamond symbol; and prose descriptions.

4. The amount of information provided on a sign may be more or less than that shown in the figures of Appendix A. Guide signs should not have more than three "bits" of information per sign (Eberhard & Berger, 1972). However, SUL signing conveys rather simple, typical information, not unusual place names. Can four or five bits be effectively communicated to the driver from one sign?

5. Should three or less bits of information be the maximum allowable per sign? Should the information be "chunked" (sequenced on more than one sign), particularly on arterials where smaller signs are used? The question here is which of the information bits should go together on a sign.

6. Should a color code be used to designate a restricted lane? This would have to be considered a secondary but reinforcing information source, but could be linked to the diamond symbol and a delineation scheme. A color code will have to be used quite sparingly, since most SUL signing is regulatory in nature and must be black and white (FHWA, 1975).

7. What type of delineation can be deployed on a part-time SUL in freeway and arterial settings?

Shoulder Lanes

8. Where a right side shoulder is used, any crossing of entrance/exit ramps presents a problem in alerting SUL and ramp drivers to potential conflicts.

9. On an arterial facility, there is a particular danger for cross traffic. If there is not clear sight distance

in both directions from a stop line before the shoulder begins, entering drivers will tend to stop with part (or all) of their vehicle on the shoulder. The hazard to HOVs is obvious. This same situation applies to cross streets, driveways, and parking lot entrances. If clear sight distance is not possible, some type of sign warning that through buses use the shoulder is necessary, e.g., WATCH FOR BUSES ON SHOULDER, 7-9 AM, MON. - FRI.

Contra-Flow Lanes

10. Arterial contra-flow bus lane SULs all currently operate in one lane and like a two-way street, albeit with a disproportionate number of lanes in each direction. Typically, these streets are signed as one-way facilities. This is, in fact, not totally true: Buses are coming from an opposing direction. This is a problem for traffic (vehicular and pedestrian) crossing the SUL.

Reversible Lanes

11. The double yellow dash does not indicate which lanes are reversing.

12. Is approach signing feasible?

13. Drivers turning left onto a reversible lane, particularly where lane control signals are not used, may not know which lane to enter. The resulting hazard is opposing cars in the same lane, with head-on or side-swipe accident potential.

CHAPTER 5
SIGNING ALTERNATIVE EXPERIMENTS

The signing questions and problems identified in the information system development effort (Chapter 4) were reviewed to determine which could be reasonably addressed through laboratory experiments. Neither time nor dollar resources were sufficient to experimentally address all of the issues, so several criteria were used to select problems for further study. These were stated as questions:

- Is totally new signing (messages/symbology) involved?
- Can the issue be tested in a laboratory setting?
- Is resolution of the issue likely to result in an operationally usable product?
- Will the research product impact a large or small number of facilities?
- What is the magnitude of the safety implication?
- Are there any cost-benefit tradeoffs or concerns?

Applying these criteria, issues 1, 2, 3, 4, 5, 10, 12, and 13 (see Chapter 4) were selected for further experimental examination. Issue 7, SUL delineation, was the subject of extensive development and laboratory testing as described in Chapter 6. Thus, four issues were not to be addressed in the laboratory; the reasons being:

- Issue 6: Color Coding
  - no meaningful measure of effectiveness for a laboratory test was identified
  - since this is redundant information, it has relatively small safety impact

- Issue 8: Shoulder SUL crossing ramps
  - a meaningful laboratory test was not identified
  - the result would impact a very small number of SULs (one)

- Issue 9: Sight distance from cross streets on shoulder SUL
  - this issue did not impact many facilities
  - no satisfactory laboratory method was noted
  - sufficient evidence exists in the literature and from accident data to address this issue and make the need for research minimal
  - results from issues 10 and 13 will provide evidence usable in designing a sign for this issue
- Issue 11: Double yellow dash does not indicate which lanes are reversing
  - like the diamond symbol, this symbol is nationally accepted and a change would probably produce more confusion than benefit.

Four experiments were designed that encompass the eight issues selected.

- Experiment 1: Wording Interpretation
- Experiment 2: Contra-Flow and Reversible Lane Signs
- Experiment 3: Symbol Evaluation
- Experiment 4: Evaluation of Sign Format and Information Load

Experiment 1:
Wording Interpretation

Purpose

The purpose of this study was to determine the various interpretations that the driving public is likely to make of phrases such as "reserved lane," "special lane," "restricted lane." The goal of the study was to select the word that, when combined with "lane," is most likely to convey the understanding that a specific lane is to be used only by high occupancy vehicles. The word is intended to alert drivers to search for the lane (located by means of other information) and to determine eligibility for use based upon the other information provided.

Since the word "restricted" has already been established by the MUTCD for such applications, this study had a dual purpose: to determine the ability of this word to evoke the intended meaning, and also to determine the relative appropriateness of all the words tested. An associated purpose was to determine whether the word "restricted" (the one most frequently used for HOV lanes) conveyed any misinformation to the driver. Whatever word is used, it is important to know how general the meaning of the word is taken to be, so that other information requirements can be met. For instance, to what extent can the word "restricted" be relied upon to convey its intended meaning, and to what extent must this meaning be augmented by other signs designating the specific vehicle types allowed?

Method

The method used was a paper-and-pencil task (see Appendix B) in which the subjects chose one of several alternative words to describe a scenario. Thirty-one scenarios were developed and

categorized for the experiment. Category I scenarios represented situations involving high occupancy vehicle (HOV) lanes. Category II scenarios represented situations wherein there was some form of use restriction but where the lane or facility was not restricted to HOVs alone, e.g., trucks use right lane, snow emergency route. Category III scenarios represented lanes or facilities that were special but not restricted, e.g., express lanes, reversible lanes. The subjects were asked to review each scenario and to choose the word that best described the situation. The list of alternative descriptions were: Prohibited, Reserved, Special, Restricted, and Exclusive. The scenarios for each category are presented in Appendix B.

The sample consisted of 42 subjects, 20 males and 22 females. The mean age of the population was 34.7 years; the mean age of the female group was 31 years and the mean age of the male group was 38.8 years. The age range was 18 to 71 years. Each subject held a valid drivers license.

Results and Conclusions

Table 8 presents the results by category of SUL type. Category I includes all those scenarios depicting a high occupancy vehicle lane. Category II includes lanes that are restricted, but not to high occupancy vehicles (e.g., trucks prohibited). Category III represents those lanes that are special but not restricted (e.g., scenic routes).

When presented with scenarios that operationally described Category I (e.g., diamond) lanes, subjects were equally likely to use the term Reserved (34.4%) as the term Restricted (33.9%). In Category II (regulatory but not diamond) lanes, the modal response (45.8%) was Restricted and in Category III (advisory, non-restricted) lanes, the modal response was Special (63.8%).

Table 8

Number and Percent Responses for Each Candidate Term by Special Lane Category

Diamond Lane Descriptive Terms	Category I		Category II		Category III	
	N	%	N	%	N	%
Prohibited	9	2.2	76	19.1	6	1.3
Reserved	140	34.4	45	11.3	42	9.4
Special	68	16.7	39	9.8	284	63.8
Restricted	138	33.9	182	45.8	57	12.8
Exclusive	52	12.8	55	13.8	56	12.6
Total	407	100.0%	397	100.0%	445	100.0%

Since the subjects clearly preferred to use Special to describe Category III situations and Restricted to describe Category II situations, the uncertainty between Reserved and Restricted in Category I can be resolved by using Reserved and leaving Restricted for Category II use. This solution would appear to avoid the equivocal responses that drivers have to the word Restricted.

Experiment 2:
Contra-Flow and Reversible Lane Signs

Purpose

The purpose of this study was to evaluate six variations of authorized one-way signs designed to be used for contra-flow operations. Additionally, this study compared various signs used to alert drivers to the entrance of reversible lanes. Arterial contra-flow lanes are usually designated by means of conventional one-way street signs, with the exact location of the contra-flow lane being indicated by lane markings and physical devices such as posts or cones. To the extent that drivers rely upon signing as the primary information input, the contra-flow operation creates a driver expectancy violation that may not be corrected early enough by the lane delineation. The expectancy violation arises in part because of the two meanings of conventional one-way signs: that all traffic must turn in the designated direction and that all lanes can be used. In a contra-flow operation the first meaning remains appropriate but the second does not. Thus, the driver who is unaware of the contra-flow operation may become confused when encountering the lane delineation and, under certain low volume conditions in the contra-flow lane, could even enter the contra-flow lane. For these reasons, it would seem that driver awareness of the situation could be improved by replacing the conventional one-way signs with signs that correctly designate both the one-way operation and the contra-flow operation. A single sign conveying both elements of information is desirable also from the standpoint of the sign proliferation problem. If a single sign can fulfill the function of two signs, some highway clutter may be avoided.

In current practice, reversible lanes are controlled by either fixed or real-time signs/signals. In many of these applications, the driver is given no advance notice of the

reversible lane situation. An information requirements analysis indicated a need for some sort of approach signing, particularly when fixed signing is the sole means by which the driver is informed of the reversible lane situation. Several alternative designs of signs used to alert drivers to the existence of lane control devices used in conjunction with reversible lanes, and some additional signs designed to warn drivers of reversible lanes, regardless of the use of real-time lane control signals, were evaluated.

Method

The experimental method involved tachistoscopic presentation of stimuli consisting of a variety of signs for both the contra-flow and reversible lane situations. Each stimulus was presented for 3 seconds and subjects were given 60 seconds to complete their response before the next stimulus was presented. For each stimulus, subjects were given a list of from 5 to 19 response alternatives and asked to check all those that applied. Subjects were given several practice trials before the experimental runs began.

In order to control stimulus exposure times and interstimulus intervals while maintaining the multiple subject capability of projected stimuli, an arrangement was devised using a large shutter in conjunction with the conventional slide projector. A Kodak Carousel 850 Auto-focus projector was set up behind an Ilex No. 5 Universal Shutter, which was mounted independently in such a way that a projector could be moved for placement and focus adjustment and could be easily dismantled for traveling. The manual trip lever of the shutter was connected mechanically to a Dormeyer D4 IL 12V. DC Solenoid activated by a homemade power supply yielding a 50-volt starting surge and 12 volts constant. Completing the activation mechanism was a Hunter

Timer Model 111-A, which provided fixed interstimulus intervals. Shutter speed was set prior to each session so that the stimulus was exposed for a constant, repeatable duration. The timing was set to allow a delay of 3 seconds (after the slide had changed) before the exposure period began, so that the Auto-focus feature had time to function. The testing room was illuminated by a single 60-watt bulb in an 8-inch reflector pointed at the ceiling. This arrangement provided sufficient light for subjects to read and fill out response sheets but did not sacrifice the image of the stimulus slides.

The experimental stimuli used in this study are presented in Figures 4 and 5. The signing for contra-flow lanes (Figure 4) consists of variations on two one-way street signs contained in MUTCD. The exception represented by the contra-flow lane is graphically depicted by an opposing arrow in signs C1 and C2. Signs C5 and C6 represent variations on the same sign, using only a single arrow. Sign C3 is simply a reduced-scale version of C4. This duplication was included to compare the effects of size against the effects of graphics. The response sets used to evaluate the contra-flow signs and reversible lane signs (Figure 5) are shown in Table 9.

Subjects were 37 female and 28 male drivers, of whom all but 3 were licensed to drive by the State of Pennsylvania. Ages ranged from 17 to 67; but 85% of the sample was under the age of 25. The mean age of the sample was 22.89 years.

The experimental design utilized within-group comparisons for two sets of 3 contra-flow signs and 2 reversible lane signs. Comparisons between signs in different sets involved between-group comparisons. Set 1 consisted of signs C1, C3, C5, R1, and R3; set 2 contained signs C2, C4, C6, R2, and R4. Subjects

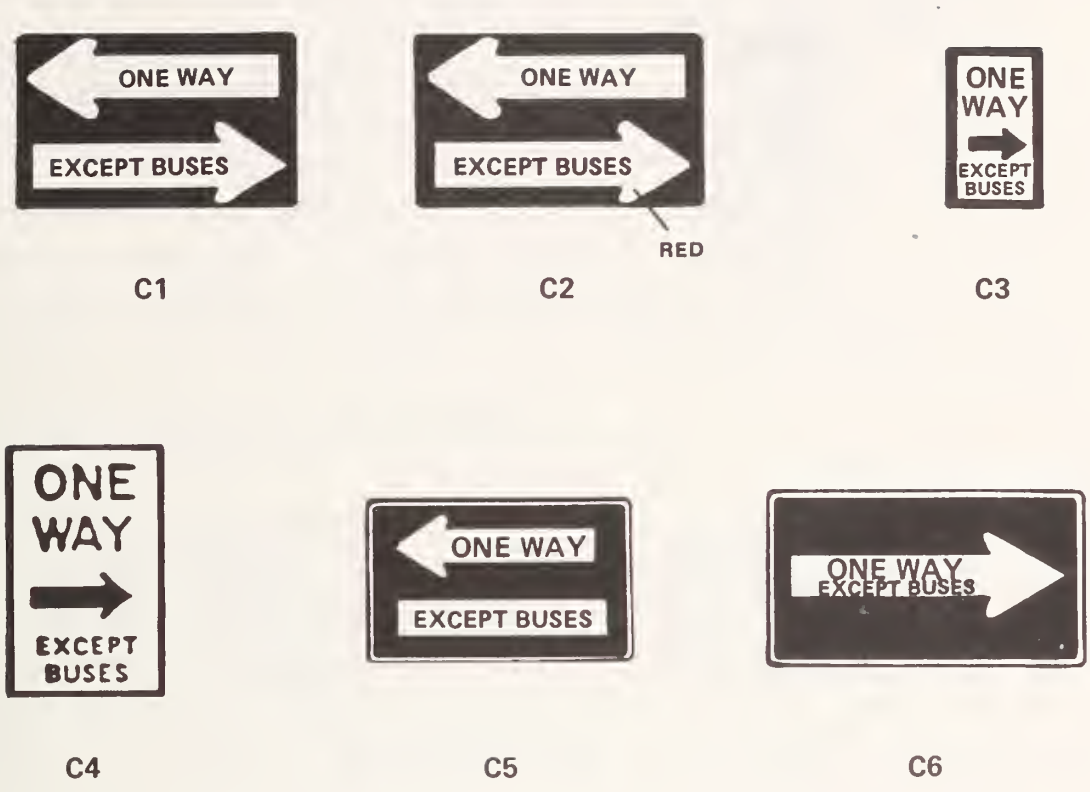

Figure 4. Candidate symbols for contra-flow lanes.

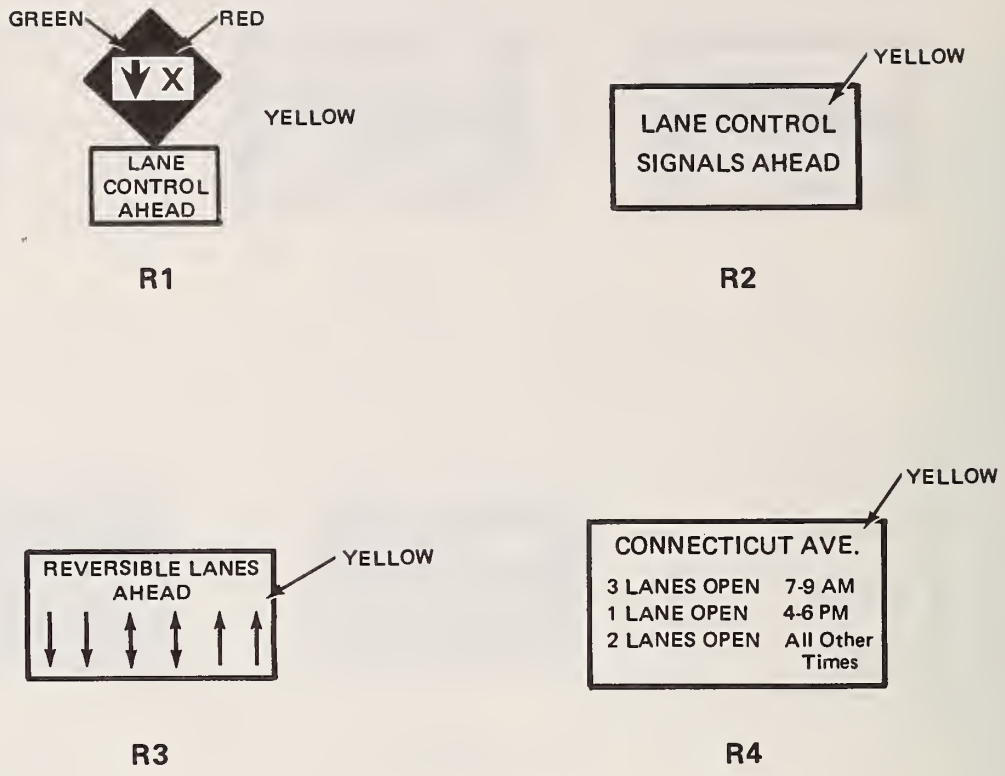

Figure 5. Candidate symbols for advance warning of reversible lanes.

Table 9

Response Alternatives for Contra-Flow and Reversible Lane Signs

Reversible Lane Response Alternatives

A. Intersections ahead will be controlled by stop lights.

B. At intersections ahead stop lights will be synchronized.

C. Signals ahead will close some lanes to certain vehicles (e.g., buses, trucks, taxis).

D. Signals ahead will indicate temporary delay in certain lanes - I should wait for green signal to proceed.

E. Signals indicate right lane closed ahead.

F. Signals ahead will specify advisory speeds for each lane.

G. Signals ahead will tell me what lane I can use.

H. Signals ahead will indicate construction in certain lanes.

Contra-Flow Response Alternatives

On the street I'm on:

A. I can turn left.

B. I can turn right.

C. I can't turn either direction.

D. Buses can turn left.

E. Buses can turn right.

F. Buses can't turn either direction.

G. Trucks can turn left.

H. Trucks can turn right.

I. Trucks cannot turn either direction.

On the cross-street:

J. All traffic is one way left to right.

K. All traffic is one way right to left.

L. Cars may be traveling left to right.

M. Trucks may be traveling right to left.

N. Buses may be traveling left to right.

O. Cars may be traveling right to left.

P. Buses may be traveling right to left.

Q. Trucks may be traveling left to right.

R. There will be no buses on this street.

S. There will be no trucks on this street.

viewing each set were divided into three groups, with each group receiving the signs in the set in a different random order.

Results and Conclusions

Contra-Flow Signs. The contra-flow signs evaluated in the study were designed to convey two types of information to the driver. The first is the direction of travel of the one-way street or, from the point of view of a driver approaching the cross-street, the direction in which turns are permitted. The second element of information is the fact that buses are permitted to travel in the direction opposite to the one-way flow. It will be recalled that the subjects were asked to mark all correct responses in the response set. It was therefore necessary to evaluate the extent to which each sign conveyed each type of information, and to assess errors of both omission and comission for the entire response set.

Table 10 shows the percentage of subjects who correctly identified the direction of flow. As might be anticipated from the fact that the direction-of-flow information was represented in a conventional manner, virtually all of the signs resulted in a high percentage of correct responses.

As shown in the top row of the table, signs C4 and C1 performed slightly better than the others, but with the exception of sign C3 there is not a significant difference among the signs. Regarding information as to the direction of bus flow, sign C4 is clearly the best of those evaluated. It is interesting to note that the two signs that contained two arrows (i.e., signs C1 and C2) resulted in the worst performance on this criterion, indicating that drivers might be confused by such a format. The performance difference between signs C1 and C2 may suggest that

the subjects were more likely to read the legend on sign C2 than on sign C1 because the use of red on the "bus" arrow drew attention to the information. The percentage of subjects who correctly identified both the direction of one-way flow and the direction of bus flow are shown in the third row of Table 10. Again, sign C4 performed the best, followed by sign C5.

Table 10

Percentage of Subjects Correctly Identifying Direction of Flow

Type of Info.	C1	C2	C3	C4	C5	C6
	%	%	%	%	%	%
Direction of One-Way-Flow	87	82	74	88	84	82
Direction of Bus Flow	19	35	39	53	42	41
Combined	16	35	29	50	42	32

Table 11 shows the percentage of subjects who made errors of commission (i.e., marking a given response that was incorrect) and errors of omission (i.e., failure to mark a response that was correct). Also shown is the percentage of subjects who made both types of errors. It should be noted that in Table 11 the higher percentages indicate poorer performance.

With regard to errors of omission, sign C4 appears to effect the best performance. However, the only statistically significant difference is between signs C4 and C1 (t = 3.09), with sign C1 resulting in the most errors.

Table 11

Percentage of Subjects Making Errors of Omission and Comission

Type of Error	C1	C2	C3	C4	C5	C6
	%	%	%	%	%	%
Omission	93.5	76.5	83.9	64.7	83.9	73.5
Comission	35.5	41.2	48.4	58.8	64.5	70.6

Using the criterion of errors of comission, sign C1 (which generated the greatest number of errors of omission) resulted in the best performance. Here, the differences between signs C1 and C2 or C3 are not statistically significant, but the differences between sign C1 and signs C4, C5, and C6 are significant at $p < .05$, with $t = 1.9$, 2.4, and 3.0 for the respective comparisons. There were no significant differences in the performance of these signs when the criterion was the percentage of subjects who made errors of both comission and omission. This is because signs that produced the most responses resulted in fewer errors of omission but more errors of comission. With signs that produced the least number of responses the reverse was the case. Omissions and commissions were therefore negatively correlated.

While the different criteria used to evaluate these signs resulted in some shifts in the rankings, sign C4 appears to provide the best overall performance. It should be apparent that this evaluation was exploratory in nature, and so did not provide the control necessary to evaluate each of the information elements in terms of content and location on the sign. Rather, the intent was to use a modified conventional one-way sign to convey the

information regarding contra-flow conditions. Considering the subject population, many of whom had never encountered a contra-flow situation while driving, the signs performed reasonably well.

Reversible Lane Warning. Of the four signs related to reversible lane operations, shown in Figure 5, only R1 and R2 were intended to satisfy the same information requirement. The two other signs in this set (R3 and R4) were included primarily to enlarge the stimulus set, but had the additional purpose of providing some indication of how well each sign conveyed the intended information. As such, signs R1 and R2 are comparable from an evaluation standpoint, while signs R3 and R4 should be considered only exploratory.

For the lane control signal signs (R1 and R2) the results showed that sign R2 was significantly better than R1. By comparison, 88.2% of the subjects responded correctly to sign R2, while only 41.2% responded correctly to sign R1. In fact, the modal response to R1 (64% of respondents) was not the correct response (G), but response (E): "Signals indicate right lane closed ahead." The red X and green arrow on this sign were obviously interpreted in an absolute sense.

This finding might reflect a lack of familiarity in the subject population with actual lane control signals, or it might be an artifact of the experimental setting. Another finding is that R2 resulted in more errors of comission--2.44 per subject, as compared to 1.81 errors of comission for R1. While the large percentage of subjects had the correct response to sign R2, greater uncertainty may be attributed to these subjects because of the large number of errors of comission. Other factors that must also be considered when choosing among these signs include the target value of R1 over R2 and the cost of fabrication.

Experiment 3:
Symbol Evaluation

Purpose

The purpose of this study was to evaluate selected alternative symbols designed to represent the various types of HOV vehicles. An additional purpose was to investigate the use of vehicle symbols bearing numerals to specify the number of passengers required for HOV qualification. The general utility of symbolic signs (including pictographs, pictograms, and other pictorial devices) has been well established. By minimizing the amount of reading that must be done, good symbolic signs can reduce the overall information processing time of users. The selection of good symbols thus allows the amount of information that can be included in a sign to be increased. Given that HOV lanes involve high traffic volumes and frequently require the presentation of large amounts of information (e.g. complex rules of use), it is important that symbolic information be evaluated.

Method

The method involved the use of tachistoscopically displayed symbolic representations of the various types of vehicles. Symbols were presented rapidly within a series, with each symbol appearing in three different series. The three presentations differed in length, with the first series having a duration of 0.5 seconds, the second a duration of 1.0 seconds, and the third a duration of 1.5 seconds. The subject's response task was to describe the type or class of vehicle represented. Subjects were given 10 seconds after each presentation in order to write down the vehicle description. A series of pilot studies was used to pre-select the symbol sets used in the study and to determine the most appropriate stimulus exposure times and interstimulus intervals. Prior to the test session, subjects were given instructions and a series of practice trials.

In addition to the symbol identification data, the "semantic differential" was utilized. This is a test designed to measure the degree of psychological meaning of an object or a concept. The procedure involves a series of 12 bipolar adjectives, separated by a 5-point scale. After viewing each stimulus symbol the subject is required to place a mark on the scale between each adjective pair to indicate his rating of the stimulus on the continuum.

In order to control stimulus exposure times and interstimulus intervals, while at the same time maintaining the multiple-subject capability of projected stimuli, the tachistoscopic projection device described in Experiment 2 was again used.

The stimuli used for the study are shown in Figure 6. The majority of the symbols were chosen for inclusion on the basis of the results of a study conducted by the American Institute of Graphic Arts for the Department of Transportation (1974).

Subjects were 37 female and 28 male drivers, of whom all but 3 were licensed to drive by the State of Pennsylvania. Ages ranged from 17 to 67; however, 85% of the sample was under the age of 25. The mean age was 22.89 years.

Design

The 3 series of stimulus presentations were comprised of 14 symbol presentations. Each of the 2 taxi symbols and each of the 3 bus symbols were shown once each, accounting for 5 stimuli. The remaining 9 stimuli were made up of 3 exposures of each of 3 carpool symbols. The 3 exposures of each symbol differed in the way in which the number of occupants required to qualify as a carpool was depicted. One method included the number within the symbol of the car. A second method pictorially symbolized

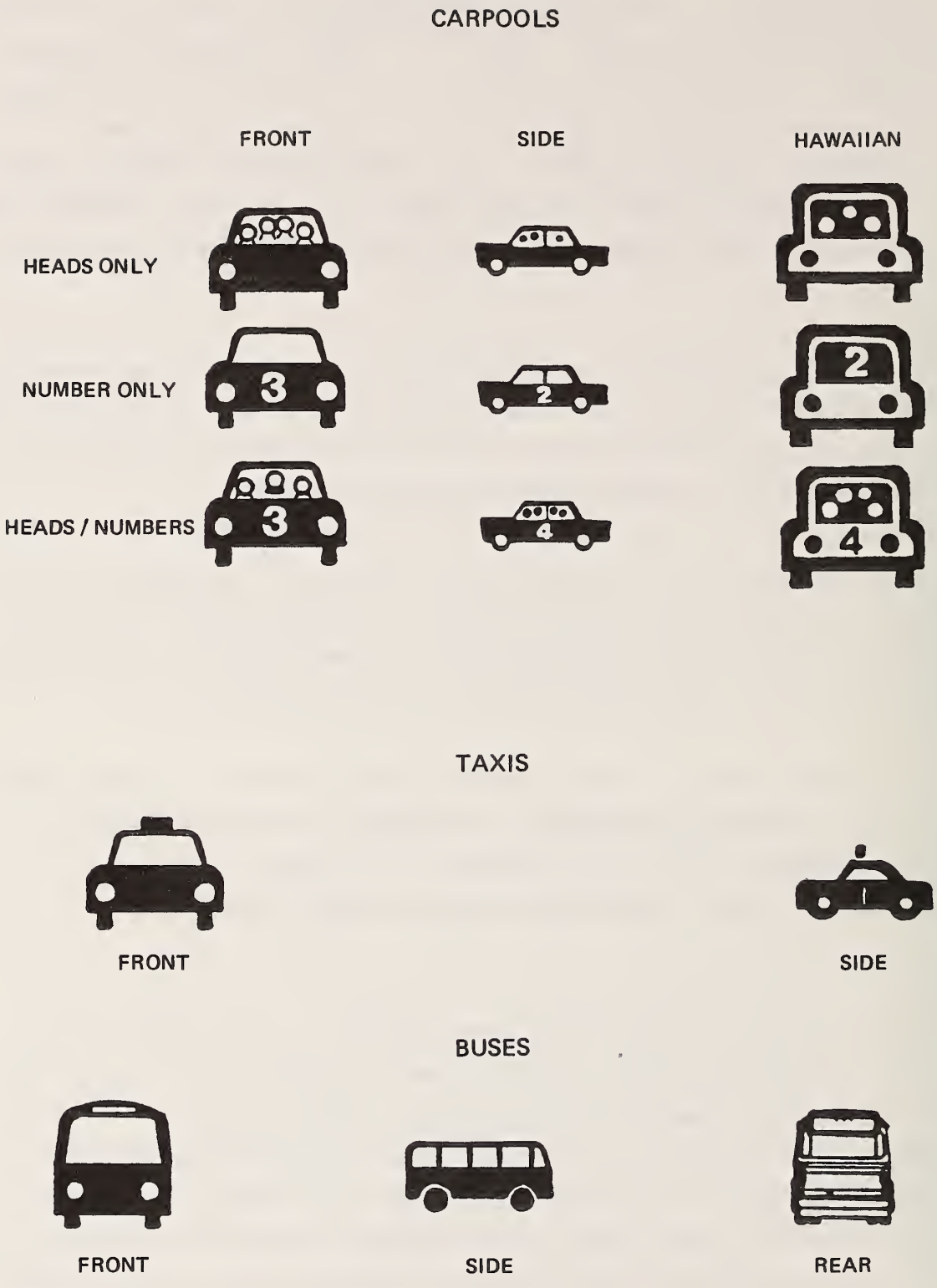

Figure 6. Symbol stimuli used for Experiment 3.

the proper number of heads in the car, while a third method included both number and heads. The actual number used (2, 3, or 4) was counterbalanced across symbol types and methods of representing occupancy requirements. All 14 stimuli were randomly ordered, with different orders used in all 3 series of presentations. Since subjects were tested in small groups of 5 or 6, the random orders of stimuli were changed for each group.

Results and Conclusions

The results showed that those symbols depicting the front view of all vehicle types resulted in more accurate identification. These performance results were, in large part, supported by the data resulting from the use of the semantic differential test. Table 12 shows the mean number of correct responses for each of the symbols, along with the t-values associated with the comparisons made. As shown in the table, the front view of the taxi (Symbol A) produced slightly more accurate identifications than did the side view, with $t = 1.95$, $.05 > p > .10$. Figure 7 shows the results of the semantic differential test for the taxi symbols. The front view of the taxi is shown to be superior on each of the scales. Likewise, the symbol depicting the front view of the bus resulted in the largest number of correct identifications (see Table 12). Here the front view was significantly better ($p < .05$) than the side or rear view. The side- and rear-view symbols of the bus resulted in essentially the same identification accuracy. However, the results of the semantic differential, as shown in Figure 8, indicate that the side view is superior to the rear view on all scales. As in the performance data, the semantic differential results show the front view symbol of the bus to be superior.

Table 12

Experiment 3 Mean Correct Response and *t*-test Values by Symbol Type

SYMBOL DESIGNATION	SYMBOL DEPICTION	MEAN CORRECT RESPONSES
A	TAXI (FRONT)	2.09
B	TAXI (SIDE)	1.85
C	BUS (SIDE)	2.66
D	BUS (FRONT)	2.91
E	BUS (REAR)	2.74
F	CAR POOL (HAWAII)	6.55
G	CAR POOL (FRONT)	7.12
H	CAR POOL (SIDE)	6.94
I	CAR POOL (# ONLY)	6.98
J	CAR POOL (HEADS)	6.15
K	CAR POOL (# & HEADS)	7.31

t-SCORES	
COMPARISON	*t*-VALUE*
A - B	1.95
C - D	-2.34
C - E	-0.68
D - E	2.27
F - G	-2.51
F - H	-1.64
G - H	-1.35
I - J	2.65
I - K	-1.39
J - K	-4.35

*$p < .02$ when $t \geq 2.39$
$p < .05$ when $t \geq 2.00$
$p < .10$ when $t \geq 1.67$
$p < .20$ when $t \geq 1.29$

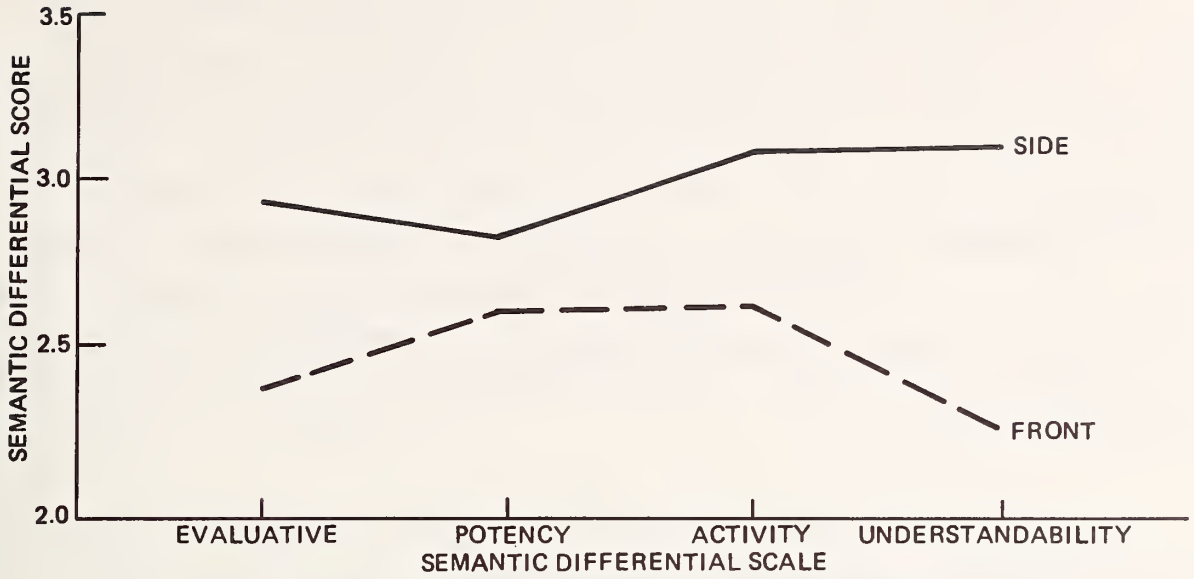

Figure 7. Semantic differential scores - taxi symbols.

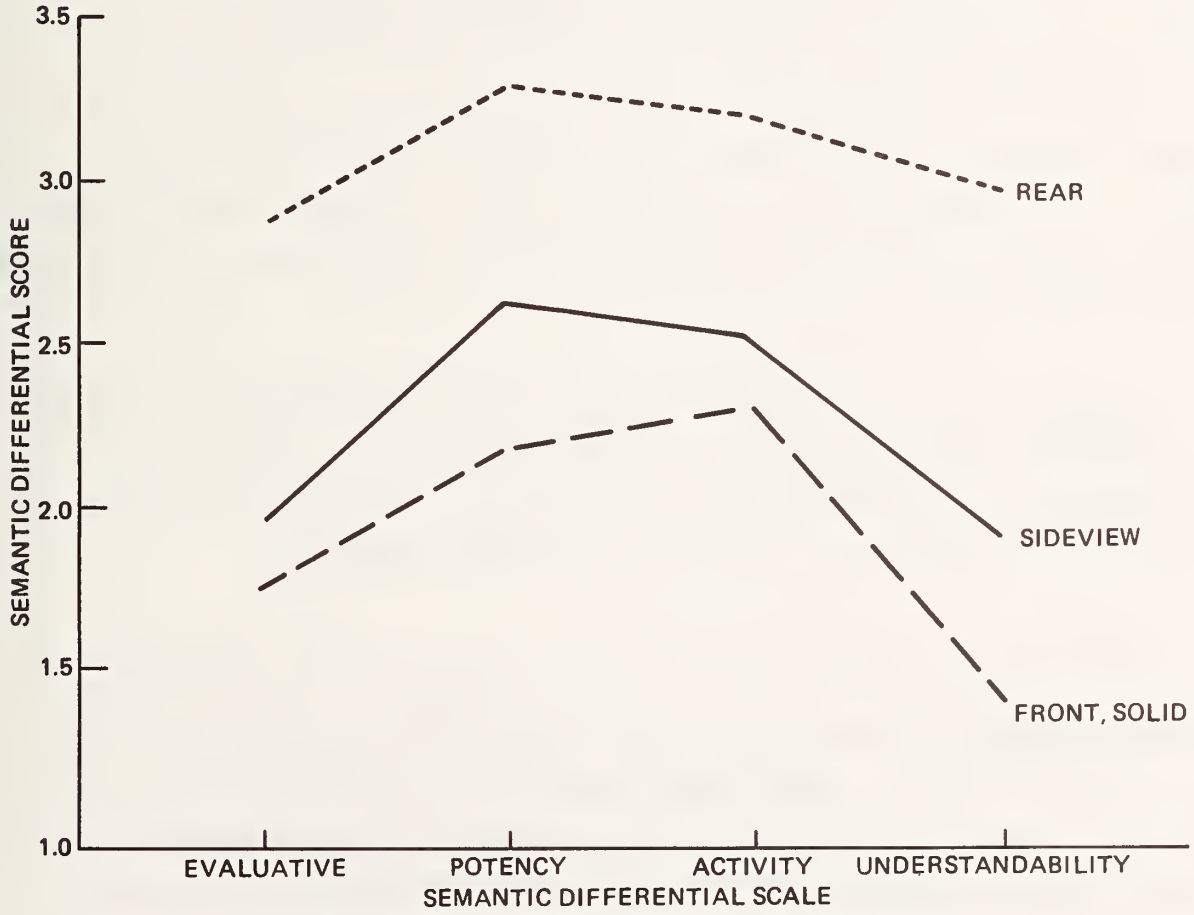

Figure 8. Semantic differential scores - bus symbols.

The Table 12 data on the carpool symbols are shown in two ways. The first set of data shows the results of the symbol collapsed across the various methods of representing occupancy requirements, while the second set shows the reverse. Again, the symbol depicting the front view resulted in the fewest errors; however, it was not significantly better than the side-view symbol ($t = 1.35$, $p < .2$). As can be seen in Figure 9, the results of the semantic differential test are in line with the performance results, the exception being the slight reversal on the potency scale.

As a method of representing the carpool occupancy requirements, the use of heads and a number was slightly (but not significantly) better than using a number alone, from the standpoint of number of errors. Both of these methods resulted in significantly fewer errors than did the use of heads only. On the semantic differential test (see Figure 10), use of a number alone was rated the highest on all except the potency scale. The results showed generally that the best symbols for taxis, buses, and carpools were those that depicted a front view of the vehicles.

With respect to carpool symbols, the PORT symbols resulted in fewer errors in vehicle identification and, when the carpool was correctly identified, the PORT symbol resulted in fewer errors in the number of vehicle occupants required.

The use of heads alone produced the greatest number of errors in determining occupancy requirements. The best method for representing occupancy requirements appears to be the use of only the number. The use of heads in addition to the number appeared not to have a substantial effect on the accuracy of identifying the symbol as a carpool or correctly identifying the carpool occupancy requirements.

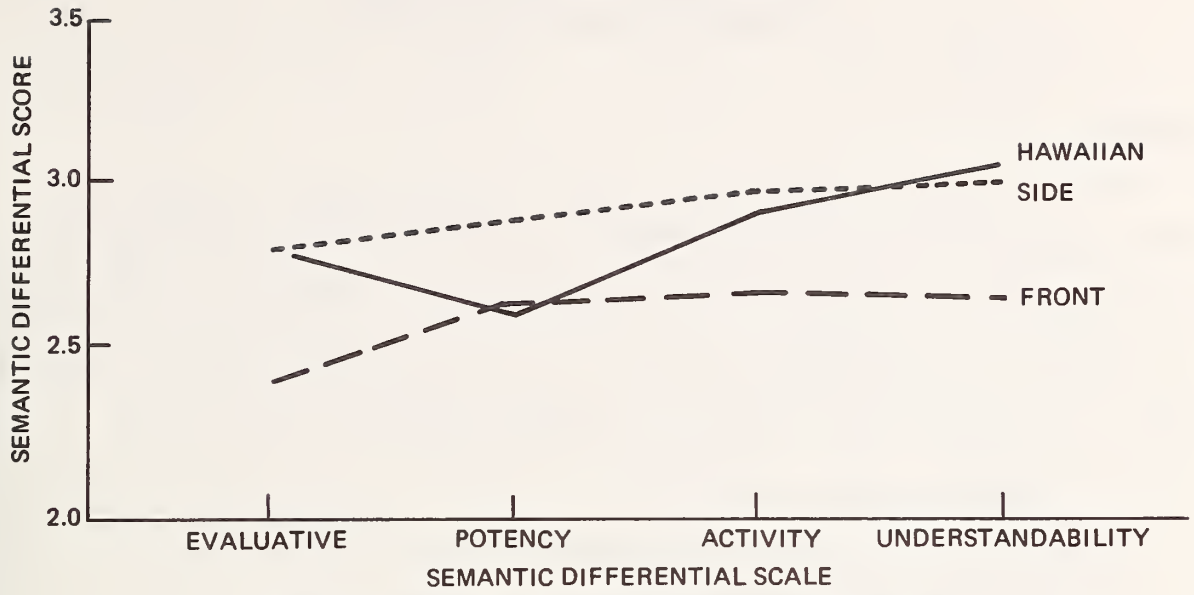

Figure 9. Semantic differential scores - carpool symbols .

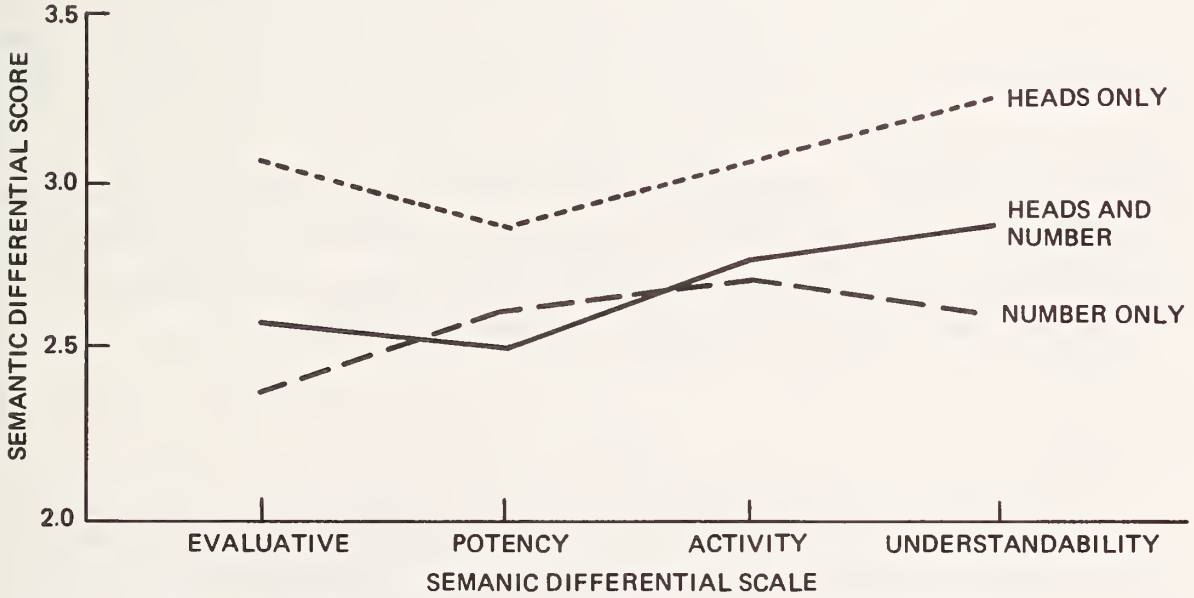

Figure 10. Semantic differential scores - carpool symbols by number, heads, and redundant number and heads.

Experiment 4:
Evaluation of Sign Format and Information Load

Purpose

The purpose of this study was to determine the amount of information that can be presented on a single HOV regulatory sign, as well as the impact of the format--symbolic or worded--in which it is presented. The information requirements analysis indicated the following information elements as essential for periodic presentation throughout many types of HOV sites.

- Vehicle types permitted
- Time period(s) of operation
- Days of operation
- Location of HOV lane
- Other rules of use.

Specifically, this study was to answer the following questions: (a) How many elements of required information can be placed on one sign; (b) How does the complexity of one element affect the number of elements that can be processed; and, (c) How does the format or arrangement of information on the sign affect the number of elements that can be processed? The results of this study provide the information needed to choose a sign format and to determine to what extent and under what circumstances information may need to be split onto two signs.

Discussion

As pointed out previously, the differences in "rules of use" from one type of HOV lane to another will result in the need to use substantially different levels of information. While improved sign formats is one means of mitigating information load effects, another means is via modification of the information presentation

strategy. Below are described the three primary factors evaluated in this study--sign format, presentation strategy, and information density. Refer to Figure 11 for illustrations of each type.

Sign Format. Sign formats were of two major types: standard and modular. The modular types depicted all vehicle types and conveyed the vehicle type "rule of use" via the conventional prohibition symbol, i.e., the red circle with slash; whereas the standard types conveyed the "rule" by a specific statement or depiction of the vehicle type(s) that was permitted. Within the standard type, the formats evaluated were word, symbol, and word plus symbol. Within the modular type, symbol and word plus symbol formats were evaluated. This provided five levels of the format variable as follows:

1. Standard-Word
2. Standard-Symbol
3. Standard-Word + Symbol
4. Modular-Symbol
5. Modular-Word + Symbol

Information Density. This variable involved the rules of use with regard to vehicle type and the hours of use. Each of these were further subdivided to specify either one or two hourly periods. The sign with the highest density information showed four vehicle types and two hourly periods, and the lowest density showed one vehicle type and one period.

Presentation Strategy. The presentation strategies are single presentation, split presentation, and repeat presentation. The single presentation depicted all of the "rules of use" information on a single sign. The split presentation involved

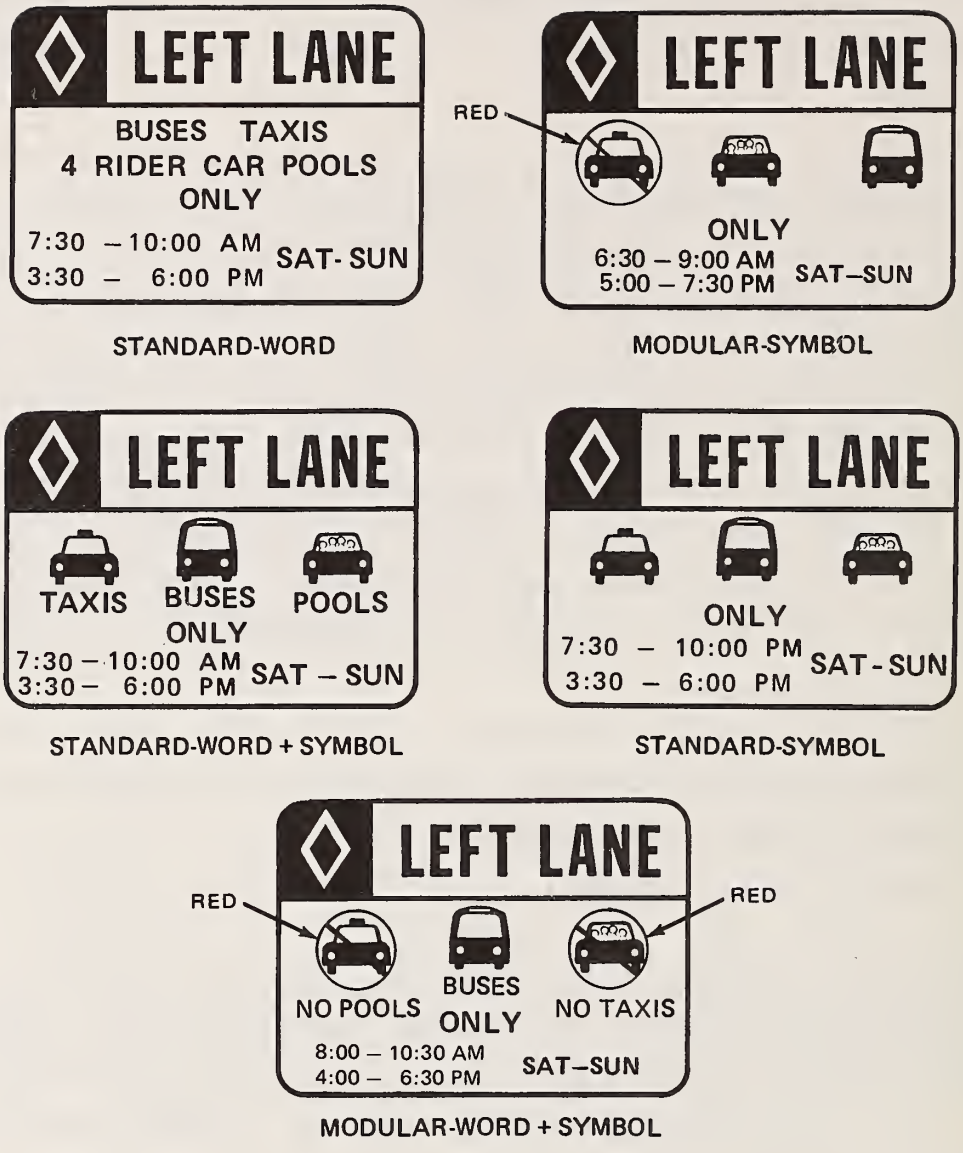

Figure 11. Example sign formats used in Experiment 4.

two successive signs with a portion of the required "rules of use" information on each sign. The repeat presentation involved two successive presentations of the single sign. It should be noted that the "repeat presentation" condition was used only for the condition involving two hourly periods, whereas the single and split presentations were used for both one and two hourly periods. Figure 12 is a matrix showing the experimental design used.

The experimental design shown in Figure 12 was relatively complex for two reasons. First, the design used both within and between subject factors, and second, the factorial arrangement of factors was incomplete. The between subject factor was formats represented by the rows in Figure 12. All other factors were tested within subjects; i.e., repeated measures. This assignment made the most sense with respect to generalization of results. In practice, drivers would be uncertain with respect to the information on a sign and the repetition of chunking of material (within subject factors), but sign format (the between subject factor) would be standardized and variation would not be encountered.

An incomplete factorial design was necessary to reduce the total number of treatment cells to a manageable number. This was obtained by including duplicate signs at only one level of hourly periods.

Method

Stimulus slides of each of the five signing strategies were prepared. These consisted of 20 combinations of signing elements in each of the five strategies, as shown in Figure 11. This design resulted in five groups of subjects each receiving 20 different stimulus treatments. Three replications of each

	Number of Vehicle Types				
	1*				
	Number of Hourly Periods				
	1		2		
	Presentation Strategy				
Formats	Single 1	Split 2	Single 3	Split 4	Repeat 5
Standard					
Word					
Symbol					
Word + Symbol					
Modular					
Symbol					
Word + Symbol					

Figure 12. Experimental design of formats (between S factor) and incomplete factorial arrangement of other sign variables (within S factors).

*These 5 columns were repeated for 2, 3, and 4 vehicle types resulting in 20 within A treatments.

treatment were presented to each subject with specific information among the replications varied to avoid learning and to control for biases, particularly with respect to vehicle types and their symbols.

In order to control stimulus exposure times and interstimulus intervals, and at the same time maintain the multiple subject capability of projected stimuli, an arrangement using a large shutter in conjunction with a conventional slide projector was used. A Kodak Carousel 850 Auto-focus projector was set up behind an Ilex No. 5 Universal shutter, which was mounted independently so the projector could be moved for placement and focus adjustments. Each subject group was presented with a stimulus slide that remained on the screen for 1.5 seconds. A one-half second interval was used between successive presentations for the split and repeat presentation conditions. The interstimulus interval was 10 seconds, during which subjects filled out a response sheet. A copy of the response sheet used and subject instructions are found in Appendix B.

Subject responses were scored with respect to correctness on five variables: identification of lane, day of week, vehicle types permitted, number in car pools, and hours of operation. The dependent variable was the proportion of correct responses to these five variables over the three replications.

A summary table of subject characteristics for each group is given in Table 13. These groups were gathered from local community colleges and civic organizations in the Washington, D.C. metropolitan area, and provided a representative sample of licensed drivers.

Table 13

Demographic Summary of Subjects Tested

Group	N	$\bar{X}$ Age	$\bar{X}$ Exp	Sex		License		Special Use Lane Experience (%)														
								Buses				Car Pools				Taxis				Symbol		
				% Male	% Female	% Yes	% No	Often	Some	Never	N.R.	Often	Some	Never	N.R.	Often	Some	Never	N.R.	Yes	No	N.R.
1	25	22.5	6.5	40	60	96	4	52	36	8	4	44	44	8	4	4	44	49	4	40	60	--
2	31	28.7	11.5	50	50	97	3	45	42	6	6	39	45	16	--	16	42	35	6	58	39	3
3	31	27.7	8.5	42	52*	94	6	39	45	10	6	45	26	19	10	10	29	42	19	48	45	6
4	24	23.2	5.4	50	46**	100	--	46	42	13	--	50	25	21	4	8	33	54	4	63	38	--
5	12	44.3	26.3	65	35	100	--	9	48	30	13	4	39	39	17	0	30	43	26	52	43	4

*2 subjects = no data

**1 subject = no data

Results

Before proceeding into a discussion of the results it should be noted that because of the incomplete factorial arrangement of independent variables, the treatment cells were separated for analysis into two separate ANOVAs. One analysis of variance, referred to as "split signing," included format (five levels), vehicle types (four levels), hourly periods (two levels), and presentation (two levels). The other analysis referred to as "repeat signing" included format (five levels), vehicle types (four levels), and presentation strategy, i.e., single presentation versus double (repeated) presentation (two levels). Each analysis is discussed separately below.

Repeat Signing Results. As shown in the ANOVA summary table (Table 14), format, presentation strategy, and number of vehicle types all produced significant F-ratios. Table 15 shows the proportion of correct responses associated with each of the levels of each factor. As shown, the Standard-Word format produced the highest response accuracy (approximately 50%), followed by the Modular-Word + Symbol format (44%). The format resulting in the least accurate responses was the Standard-Word + Symbol, with a response accuracy of about 35%. While the differences among the various sign formats are statistically significant, the difference of approximately 15% between the best and worst is not substantial in a practical sense, particularly in consideration of the fact that the stimulus presentation time used for the study (1.5 second) was shorter than would be typical in actual practice. That is, one would assume that the differences between formats would be reduced as information presentation time was increased.

The effects of presentation strategy were also significant, but small from a practical standpoint. The repeat presentation

Table 14

Analysis of Variance Summary Table
(Repeat Signing)

Source	Sums of Squares	Mean Squares	DF	F Ratio
Between Subjects				
Sign Format (Factor A)	9.46	2.365	4	5.660*
Error	48.04	0.418	115	
Within Subjects				
Presentation Strategy (Factor J)	3.19	3.193	1	57.146*
AJ	0.24	0.698	4	1.091
Error	6.43	0.559	115	
Number of Vehicle Types (Factor K)	34.24	11.413	3	144.772*
AK	4.05	0.338	12	4.284*
Error	27.20	0.788	345	
JK	0.22	0.717	3	1.113
AJK	2.08	0.174	12	2.695
Error	22.22	0.644	345	

*Alpha $\leq$ 0.05

Table 15

Repeat Signing Analysis (Response Accuracy)

	% Correct Responses
Sign Format (Factor A)	
Standard-Word	.495
Standard-Symbol	.427
Standard-Word + Symbol	.347
Modular-Symbol	.395
Modular-Word + Symbol	.439
Presentation Strategy (Factor J)	
Single Presentation	.392
Repeat Presentation	.445
Number of Vehicle Types (Factor K)	
One Vehicle Type	.540
Two Vehicle Types	.455
Three Vehicle Types	.405
Four Vehicle Types	.280

of the signs resulted in only slightly more than a 5% increase in accuracy, hardly enough of an increase to justify the repeat strategy. While it may be hypothesized that the repeat strategy would be helpful for signs characterized by higher information density, e.g., word + symbol signs with four vehicle types, the lack of a significant interaction between presentation strategy and either format or number of vehicle types indicates that the repeat strategy has no reliable differential effect on the various formats, regardless of the amount of information displayed.

The effects of increasing amount of information are, however, reflected in the response accuracy associated with the number of vehicle types displayed. As shown in Table 15, the percentage of correct responses for signs involving one vehicle type was nearly double that of signs depicting four vehicle types. While the number of vehicle types permitted to use an HOV is a function of the facility and cannot be controlled as can sign format and presentation strategy, the results are important in that the significant difference in response accuracy between either one, two, or three vehicle types and four vehicle types suggests that the necessity to sign for four vehicle types may produce an information overload for the driver.

The substantial effect of number of vehicle types signed for is reflected in the significant interaction between this factor and formats, as shown in Figure 13. As can be seen, there is a general decrease in performance for all formats as the number of vehicle types is increased.

Table 16 summarizes the rank order and proportion of correct responses of sign presentation methods for four levels of number of vehicle types. The standard word format was the best format

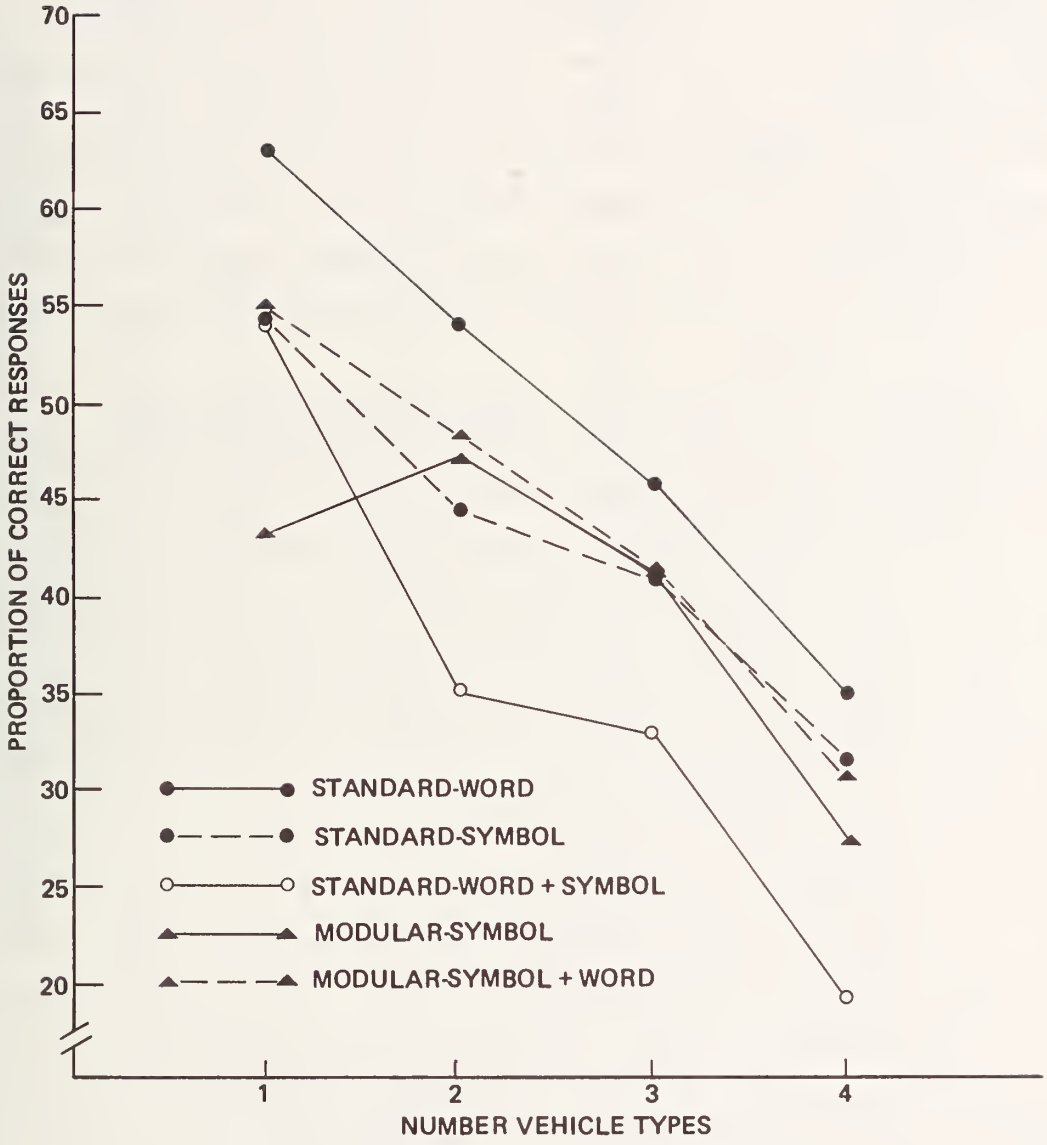

Figure 13. Sign format x number vehicle types (Repeat signing analysis).

Table 16

Rank Order of Sign Presentation Methods, Average Rank, and Mean Proportions for Four Levels of Vehicle Types

	Format	Repeat	Vehicle Types 1	2	3	4	X Rank	P
1	Standard-Word	Yes	1	2	1	1	1.25	.52
2	Standard-Word	No	2	3	3	5	3.25	.47
3	Modular-Word + Symbol	Yes	4	1	7	3	3.75	.47
4	Standard-Symbol	Yes	5	5	5	2	4.25	.45
5.5	Standard-Symbol	No	6	7	6	4	5.75	.41
5.5	Modular-Symbol	Yes	8	6	2	7	5.75	.43
7	Modular-Word + Symbol	No	7	8	4	6	6.25	.41
8	Word + Symbol	Yes	3	9	8	9	7.25	.39
9	Modular-Symbol	No	10	4	9	8	7.75	.36
10	Standard Word + Symbol	No	9	10	10	10	9.75	.31

overall, whether or not repeat signing was used. The standard word with repeat signing was the best sign presentation method for all levels of vehicle type, except level two where it was second best. There was not a significant difference, however, between the two best methods. When repeat signing was not used, the standard word format was best for all levels of vehicle type except level four, where it ranked just below the standard symbol format. This difference was also not significant. Additional tests of significance showed that the standard word/no repeat format was never significantly poorer than the same format with repeat signing. The greatest difference occurred with four vehicle types where the standard format resulted in a 37% rate of correct responses with repeat signing and a 32% rate without.

Split Signing Results. The analysis of variance summary for the split signing analysis is shown in Table 17. Unlike the repeat signing results, sign format did not produce a significant F-ratio with the split signing presentation strategy. However, it should be noted that from the standpoint of response accuracy, as shown in Table 17, the formats maintain the same ranking as they did for the repeat signing analysis. The higher levels of response accuracy and the narrower range between formats (resulting in a non-significant difference) in large part appears to be a function of the inclusion of both one and two hourly periods for the split signing analysis and the inclusion of only two hourly periods in the repeat signing analysis. That is, an assessment of the split signing condition using only the responses from the stimuli involving two hourly periods shows that the range of response accuracy from the "best" format to the "worst" format is approximately 13% as compared to the repeat signing condition of 15%. If both hourly periods are included, the range from "best" to "worst" format was 8.6%. This suggests that the number of hourly periods displayed was the primary factor that accounted for the significant format effect.

Table 17

Analysis of Variance Summary Table
(Split Signing)

Source	Sums of Squares	Mean Squares	DF	F Ratio
Between Subjects				
Sign Format (Factor A)	6.60	1.650	4	1.824
Error	104.00	0.904	115	
Within Subjects				
Number of Vehicle Types (Factor J)	73.61	24.535	3	265.341*
AJ	6.29	0.525	12	5.673*
Error	31.90	0.925	345	
Number of Hourly Periods (Factor K)	14.17	14.170	1	149.860*
AK	2.37	0.592	4	6.258*
Error	10.87	0.946	115	
JK	2.06	0.687	3	10.386*
AJK	0.83	0.694	12	1.048
Error	22.83	0.662	345	
Presentation Strategy (Factor L)	33.68	33.678	1	321.852*
AL	1.94	0.484	4	4.630*
Error	12.03	0.105	115	
JL	0.78	0.261	3	3.623
AJL	3.39	0.283	12	3.934*
Error	24.81	0.719	345	
KL	1.10	1.103	1	18.989*
ALK	2.34	0.585	4	10.078*
Error	6.68	0.581	115	
JKL	0.56	0.186	3	2.410
AJKL	1.15	0.954	12	1.233
Error	26.69	0.774	345	

*Alpha $\leq$ 0.05

With the exception of format, all other main factors produced significant F-ratios, as did all of the two-way interactions except the interaction between presentation strategy and number of vehicle types. Table 18 shows the proportion of correct responses for each level of each of the main factors. As with the data from the repeat signing, the addition of vehicle types has a substantial effect upon response accuracy. While the response accuracy for the split signing data set is slightly higher at each level, most likely as a function of the inclusion of both one and two hourly periods, the range from one vehicle type to four vehicle types is approximately the same as that for the repeat signing data set.

The improvement in response accuracy produced by the split signing strategy was approximately 13%. While the incomplete factorial design does not permit a direct comparison of this presentation strategy with the repeat strategy, some idea of the relative effectiveness of the two strategies can be gained by assessing the data from the split strategy using only the responses for those stimuli that utilized two hourly periods. This shows that the difference in response accuracy between single and split presentations was 10.8%, whereas the difference between single and repeat presentations was 5.3%. Thus, it appears that more is gained by the split presentation strategy under the conditions of the experiment.

Figure 14 shows the interaction of sign format and number of vehicle types. While the interaction is significant, the relationship is certainly not clear enough to provide any conclusive "positive" statement of format. Little can be gleaned from this result except that the Standard-Word + Symbol format is the least desirable. The relationship between format and

Table 18

Split Signing Analysis (Response Accuracy)

	% Correct Responses
Sign Format (Factor A)	
Standard-Word	.521
Standard-Symbol	.493
Standard-Word + Symbol	.435
Modular-Symbol	.486
Modular-Word + Symbol	.506
Number of Vehicle Types (Factor J)	
One Vehicle Type	.617
Two Vehicle Types	.525
Three Vehicle Types	.460
Four Vehicle Types	.352
Number of Hourly Periods (Factor K)	
One Hourly Period	.531
Two Hourly Periods	.455
Presentation Strategy (Factor L)	
Single Presentation	.422
Split Presentation	.554

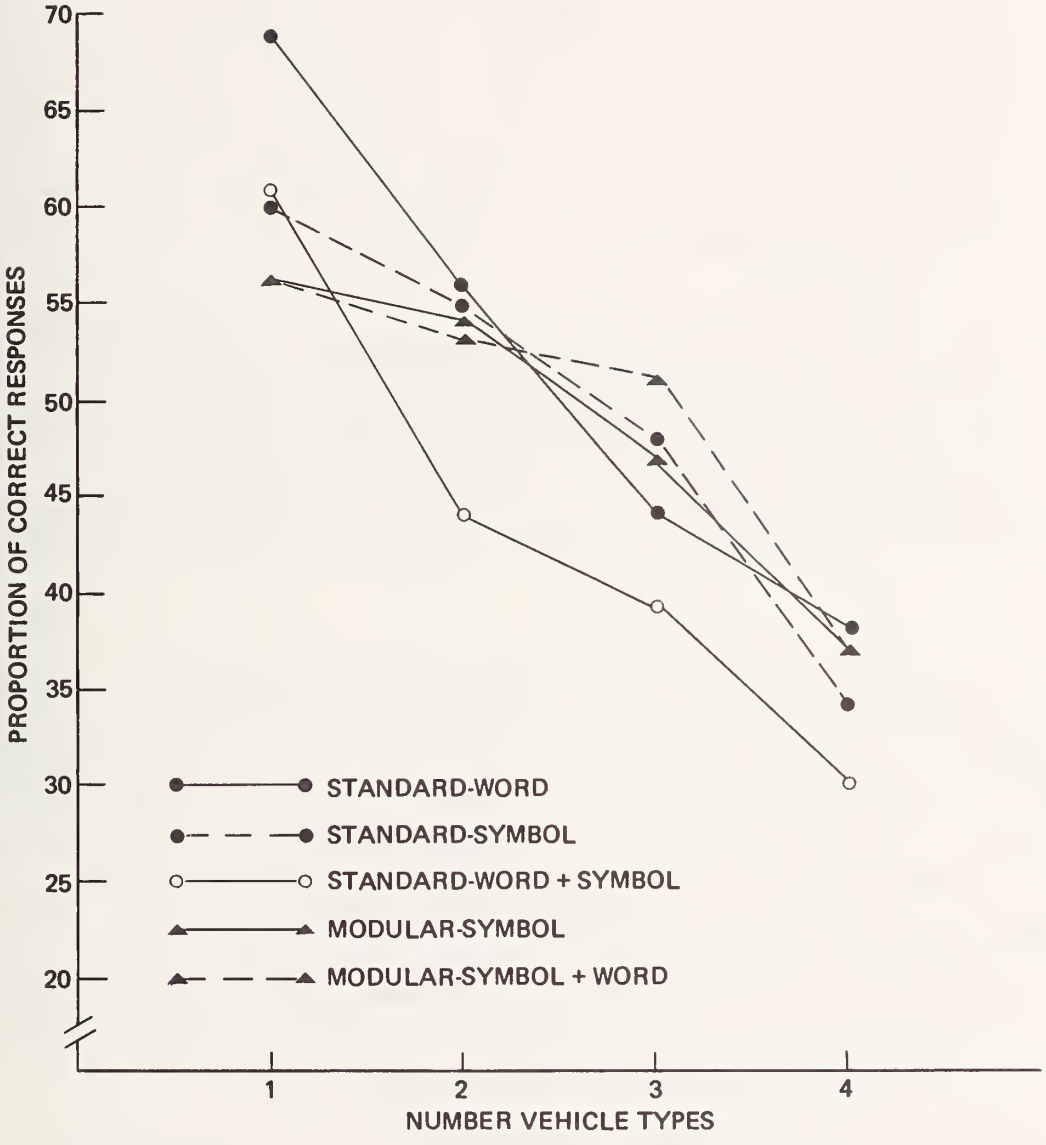

Figure 14. Sign format x number vehicle types displayed (Split signing analysis).

number of hourly periods, shown in Figure 15, indicates that while there is little difference between format when only one hourly period is required, response accuracy is maintained slightly better with the Standard-Word format than with the others when two hourly periods are required. The relationship between format and presentation strategy is shown in Figure 16. The plot indicates the gain in response accuracy for each of the sign formats. As might be expected, the gains are least for those formats that produced the most accurate responses as reported in the analysis of main effect; with the least gain being 8% for the Standard-Word format and 9% for the Modular-Word + Symbol format.

The relationship between presentation strategy and number of hourly periods is shown in Figure 17. While response accuracy under the split presentation condition decreased slightly more with the presentation of two hourly periods, the advantage of the split presentation strategy in terms of overall response accuracy is clear.

Table 19 summarizes the rank order and proportion of correct responses of sign presentation methods for various levels of information density. The data clearly show the advantage of split signing. With one exception, there were no significant differences* among the four best presentation methods. The single exception was that the second best method (standard symbol/split) was significantly poorer than the other three when there was one vehicle type and two hourly periods. Any of the four methods would appear to be satisfactory.

Although the best four presentation methods involved split signing, a relevant question is how much better are these methods

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*Tukey's test for significant differences.

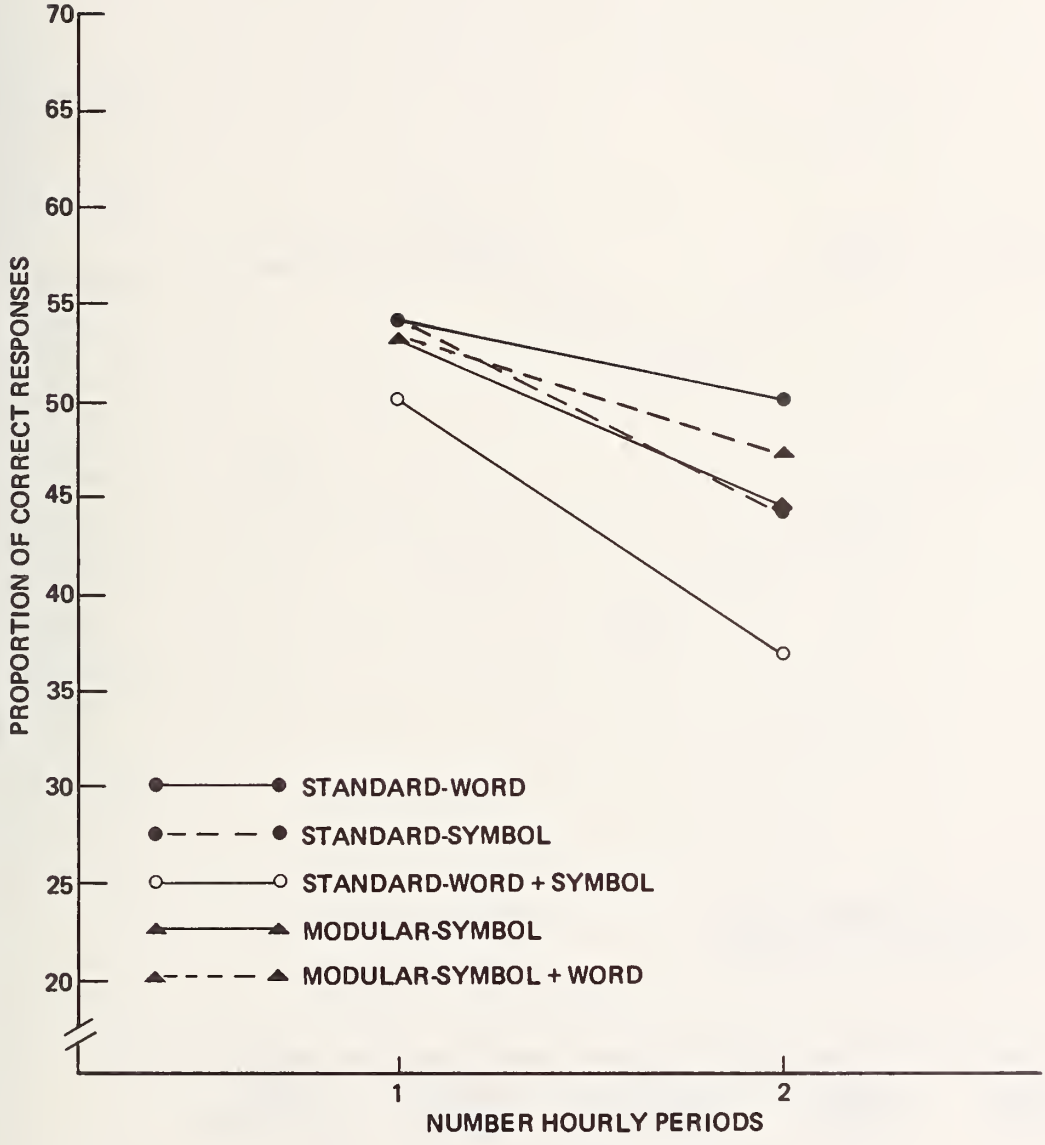


Figure 15. Sign format x number hourly periods displayed (Split signing analysis).

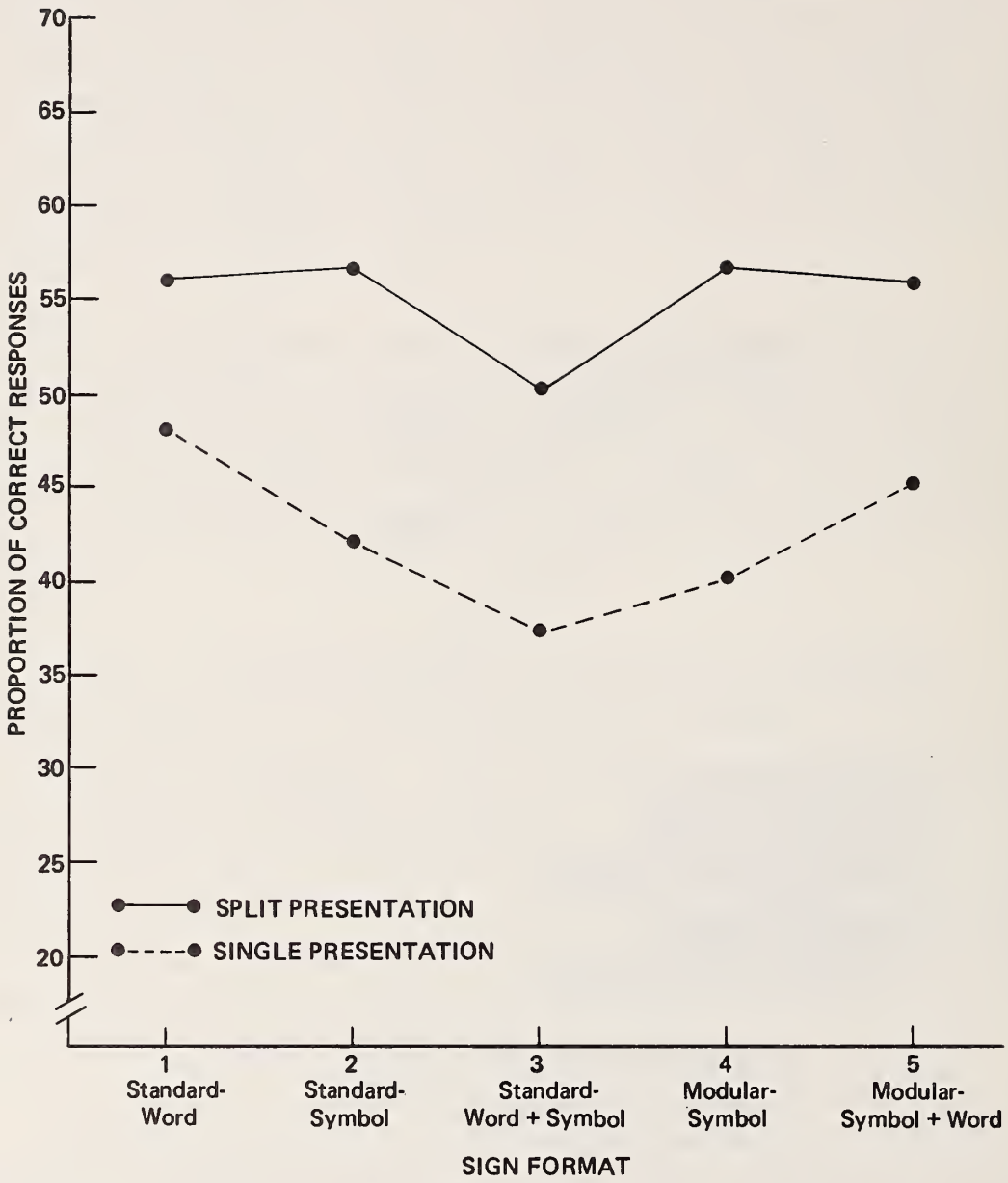


Figure 16. Presentation strategy x sign format (Split signing analysis).

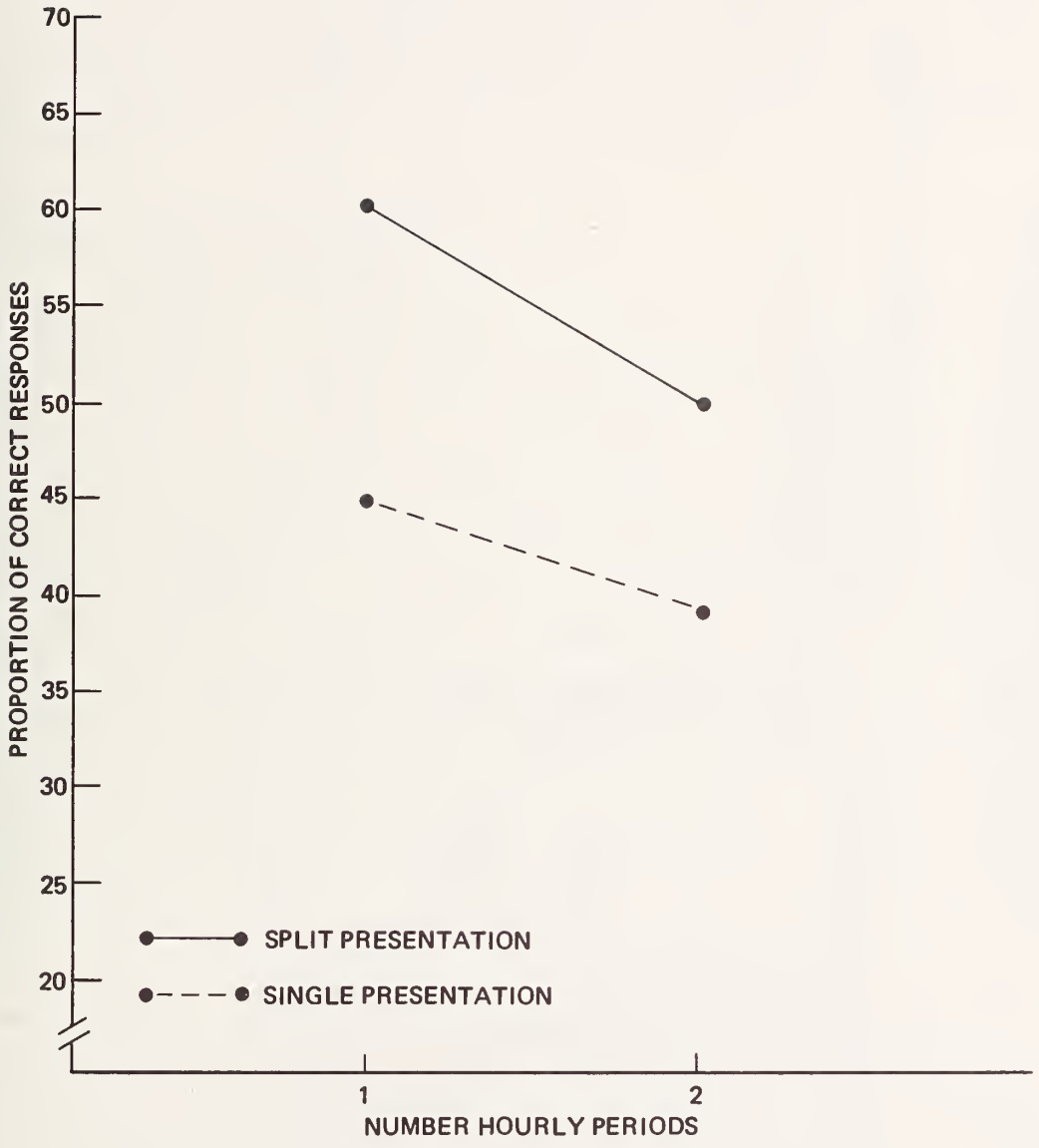


Figure 17. Presentation strategy x number hourly periods displayed (Split signing analysis).

Table 19

Rank Order of Sign Presentation Methods, Average Rank, and Mean Proportions for Eight Levels of Information Density

Sign Presentation Method			Level of Density									
			Vehicle Types	1	1	2	2	3	3	4	4	
Overall Rank	Format	Split?	Hourly Periods	1	2	1	2	1	2	1	2	$\bar{X}$ Rank	P
1	Modular-Symbol	Yes		4	2	2	4	2	2	1	3	2.50	.57
2	Standard-Symbol	Yes		3	6	1	2	1	3	2	5	2.87	.57
3.5	Standard-Word	Yes		1	1	4	3	6	5	3	1	3.00	.56
3.5	Modular-Word + Symbol	Yes		5	4	3	1	4	1	4	2	3.00	.56
5	Standard-Word	No		6	3	6	5	7	4	7	4	5.50	.48
6	Standard-Word + Symbol	Yes		2	5	5	8	5	6	5	8	5.50	.50
7	Modular-Word + Symbol	No		7	8	10	9	3	7	6	7	7.12	.45
8	Standard-Symbol	No		9	7	7	7	9	9	10	6	7.75	.42
9	Modular-Symbol	No		10	10	9	6	9	9	9	9	8.87	.40
10	Standard-Word + Symbol	No		8	9	8	10	10	10	8	10	9.12	.37

than the best format using a single presentation. The standard word format with single presentations was the fifth best presentation method overall. Tests of significance indicated that it was never poorer than the modular word and symbol/split, poorer than the standard word/split at only one level of density (four vehicle types/one hourly period), poorer than the modular symbol/split at two levels of density (two or four vehicle types/one hourly period), and poorer than the standard symbol/split at three levels of density (two, three and four vehicle types/one hourly period).

Analysis and Conclusions

If a single format were to be recommended on the basis of these data, it would be the Standard-Word format. Further, the recommended presentation strategy would be the split presentation as opposed to the repeat or single strategy. As shown, the Standard-Word with split presentation was either best or not significantly poorer than the best at all levels of information density. However, it should be noted that while the data indicate an advantage for the split presentation, the nature of its improvement is somewhat equivocal due to the interaction of hourly periods and split signing. The improvement obtained from split signing was greater at one hourly period than at two. Only at one hourly period was the improvement obtained with split signing significant. When there were two hourly periods, the best formats with split presentations were not signficantly better than the best format (Standard-Word) with a single presentation. While the interaction of vehicle types and split (or repeat) signing was not significant, an examination of the cell means supports a similar trend--the greater the number of vehicle types the less the effect of split signing. Together these findings suggest that the effect of a split signing is negatively correlated with information density (i.e., number of vehicle types or hourly periods).

The negative correlation between information density and split signing can be explained by postulating an interaction of split signing and stimulus presentation time. With short presentation times and high density, split signing cannot improve generally poor performance. At longer presentation times and high density, split signing is not necessary because performance is generally satisfactory. Split signing would seem to have its greatest effect only when presentation time is inadequate for the level of information density. If this untested hypothesis is true, it suggests that in areas where presentation time is short (e.g., high speed, truck blockage, etc.), a reduction in information density is the best way to obtain an improvement. Where presentation time is high (e.g., large signs, slow speeds, or no truck blockage), one sign is probably adequate. However, where presentation times are unpredictable and variation in presentation time is expected, split signing will have its greatest advantage.

It should be noted that these conclusions are based solely upon the experimental results. The purpose of the study was to determine which format(s) and presentation strategy should be field tested in a subsequent phase of the project. While the recommendations would most likely be applicable under conditions such as a freeway HOV lane where truck blockage would result in short information presentation times for a number of drivers, they may not apply to other types of HOV lanes. For example, on an HOV on a city street where speeds are low, the split signing strategy may result in a longer than desirable time between the presentation of the two signs.

Further, while reasonable confidence can be placed on the recommended format, the fact is that the symbols used for various vehicle types were new to the subjects, particularly as used in the modular formats. It is possible that once drivers become familiar with the symbols under operational conditions, many of the format differences would not be observed.

Finally, the conclusions are based on overall conditions of information density. Given a specific application involving a specific level of density and assumed presentation time, the result should be reviewed to determine which format/presentation strategy seems most appropriate for that condition.

Chapter Synthesis and Summary

Four experiments were conducted to investigate various SUL signing issues or problems raised during the information analysis and initial information system design tasks (see page 56). Findings from these experiments are presented as responses to the eight issues.

1. Is the word "restricted" the best verbal definition of the diamond symbol?

   Finding: The terms "reserved" and "restricted" were equally applicable to diamond lanes. However, the term "restricted" was most applicable to lanes with non-HOV limitations, e.g., trucks prohibited. Ideally, the term "reserved" could be used for HOV lanes and "restricted" for other types of lane limitations. Since the term "restricted" is already widely used and adequately conveys the intended meaning, there may be little benefit from changing such a widely adopted term.

2. The verbal designations for buses, carpools, taxis, and vanpools take considerable space, especially when several are used on one facility. Do symbols adequately convey the needed information? Which symbol is sufficiently legible and meaningful?

   Finding: The front view of all vehicle types tested (car, taxi, bus) resulted in the most accurate identification. The PORT symbol was the most successful of the car symbols (lst column, Figure 6).

3. Carpools are defined variously on SULs, ranging from two to four persons per car. Different presentation methods of such information need to be studied further.

   Finding: Designating a number (digit) on the symbol was the best method for representing occupancy requirements. The use of heads in addition to the number did not appear to have a substantial effect either on the accuracy of identifying the symbol as a carpool or on correctly identifying the occupancy requirement.

4. The amount of information provided on a sign may be more or less than that shown in the figures of Appendix A. Can four or five "bits" of information be effectively communicated to the driver from one sign?

   Finding: Yes. However, this result is limited to very specific, concise information, e.g., time, days, vehicle types, familiar place names, route directions, or numbers.

5. If only three or less bits of information are allowable per sign, should larger amounts of information be sequenced or chunked?

   Finding: Split or chunked presentation was more effective with medium information density and short presentation time. Thus, it appeared applicable mainly to situations where drivers would have only quick glances at SUL signs, e.g., urban arterials. Short exposure time and high information load appeared to be a difficult situation, which was not ameliorated by chunking. Field testing to verify and clarify the laboratory results is warranted.

6. (Issue #10) Currently, arterial contra-flow bus lane SULs operate in one lane and like a two-way street, albeit with a disproportionate number of lanes in each direction. Typically, these streets are signed as one-way facilities. This is, in fact, not totally true, since buses are coming from an opposing direction. This is a problem for traffic (vehicular and pedestrian) crossing the SUL.

   Finding: A variation of a one-way sign (large, with the added words "except buses") most clearly conveyed to drivers the idea of looking for buses (see Figure 4, sign C4, page 67).

7. (Issue #12) Is approach signing feasible?

   Finding: A single verbal message sign was more effective than a symbol sign (see sign R2, Figure 5, page 68).

8. (Issue 13) Drivers turning left onto a reversible lane, particularly where lane control signals are not used, may not know which lane to enter.

   Finding: None of the sign concepts tested satisfactorily conveyed the desired message.

These experiments dealt only with signing. The following chapter explores the delineation of SULs.

CHAPTER 6

DEVELOPMENT OF DELINEATION ALTERNATIVES FOR SPECIAL USAGE LANES

The development of delineation designs for field tests was concentrated on alternative systems for concurrent flow lanes. While the criticality of markings on contra-flow and reversible lanes is obviously quite high, the marking systems currently used appear to be successful. This is not the case for concurrent flow lanes, particularly those serving as SULs part-time. Concurrent flow is the most frequently installed SUL, and its use is rapidly expanding.

The delineation design dilemma in regard to concurrent flow SULs is that the design must communicate two messages: restricted for use to certain vehicles during rush hours, and then open to general traffic, parking, etc. during off-peak periods. Essentially, the marking must prohibit entry to certain types of vehicles at certain times, and then permit entry (or reversion to other purposes) at other times. Although an SUL marking would usually have the benefit of signing to explain marking symbology, the experiments described in the following sections were designed to answer the following questions:

- Do various types of SUL delineation/marking designs have inherent prohibitive/permissive meanings to drivers?
- If not, which designs must readily take on or are associated with the desired meaning?
- If necessary, what type of signing may be needed to explain or confirm the intent of the marking scheme?

Essentially, Task 3 studies were devoted to driver understanding of delineation marking treatments.

The primary research tool used in the delineation studies was the pair-comparison technique, based on the Law of Comparative Judgement formulated by Thurstone (cited in Guilford, 1954). In the method of pair comparisons, all stimuli to be evaluated are typically presented to the observer in all possible pairs, and the observer judges which is a greater quantity than the other according to some predefined criterion. The response of the observer is ostensibly a comparative judgment, and from the resulting responses across all pairs judged, a scale of values is obtained illustrating the distances between stimuli on a psychological scale of meaning.

The meaning in this case is permissiveness vs. prohibitiveness, as indicated by any given lane line design. Pairs of design stimuli were presented to the driver, and his task was to select one over the other according to a scenario of a given driving situation. The experiments proceeded in a step-wise fashion beginning with discovery of inherent meanings devoid of SUL scenarios, to associations of the optimal markings with benefit of some signing, to assessment of a system concept for concurrent flow SULs. The final point operated as a kind of lead-in preparatory initiative to the field evaluation of Task 5.

Outline of Studies

The following is an outline of the delineation studies conducted:

Experiment 1: Evaluation of the inherent prohibitive-permissive aspects of 18 candidate SUL delineation treatments (laboratory study)

Experiment 2: Evaluation of the effects of width and density of marking design elements on driver decisionmaking (laboratory and controlled field study)

Experiment 3: Observational evaluations of driver and pedestrian behaviors on currently operating SULs (field feasibility study)

Experiment 4: Evaluation of final delineation and signing issues prior to system deployment in full field evaluation (four laboratory studies):

(1) Use of orange cones and posts as delineators of SULs

(2) Perception of various marking schemes as connoting a shoulder/breakdown zone

(3) Association of delineation scheme on pavement with symbolic representation on signing

(4) Number and placement of SUL signs along the roadway.

The following pages present write-ups of each experiment in the order listed above.

Experiment 1:
Inherent Meaning of Delineation Designs

Purpose

Experiment 1 was specifically committed to determining whether selected delineation treatments had any inherent prohibitive-permissive meaning for drivers relative to lane changing.

Method

Development of delineation treatment designs started with brainstorming by BioTechnology and Institute for Research staff. Resulting ideas were critiqued from several perspectives, e.g., space and application requirements; potential meanings; and conflicts in meaning or driver expectancy with other signs, markings, or symbols. Fifteen treatments survived this initial critique and were submitted to FHWA for review and comment. Based on FHWA suggestions, 11 designs were finally selected for experimental testing. Variations on several of these designs (e.g., color coding) brought the total number of treatment candidates to 18. These are listed and illustrated in Figure 18.

Each of the treatments was drawn on a clear acetate sheet. These sheets were laid on an artist's rendering of a 3-lane freeway-type roadway. The illustration shown in Figure 19 is, of course, greatly reduced and not in color. Treatments were photographed in pairs so that every design was seen with every other design. Placement on the left or right side of the roadway picture was randomized. The resulting 35mm slides were shown to groups of 10 subjects via a tachistoscope (1 second presentation, 5 second interstimulus interval). No mention was made of SULs since this was a study of inherent, not associative, meaning

1. Conventional dash (baseline or no treatment condition)

2. Wide dash (at least 8 inches)

3. Broken-solid combination (white)

4. Double dash (white)

5. Conventional dash - MUTCD Diamond (15' line, 25' gap) diamond every 1000' or 500'

(All 2 feet wide)

6. Diamond with solid line (white)

7. Repeat Number 5 with filled in (solid) diamond

8. Diamond with dash line (white)

9. Diamond with connecting line (white)

10. Diamonds only

(All 2 feet wide)

11. Diagonal crosshatch (left slant)

12. Diagonal crosshatch (right slant)

13. Number 2 in bright yellow-green (BYG)

14. Number 2 in light blue

15. Number 7 in BYG

16. Number 7 in light blue

17. Number 9 in BYG

18. Number 9 in light blue

Figure 18. Delineation design options.

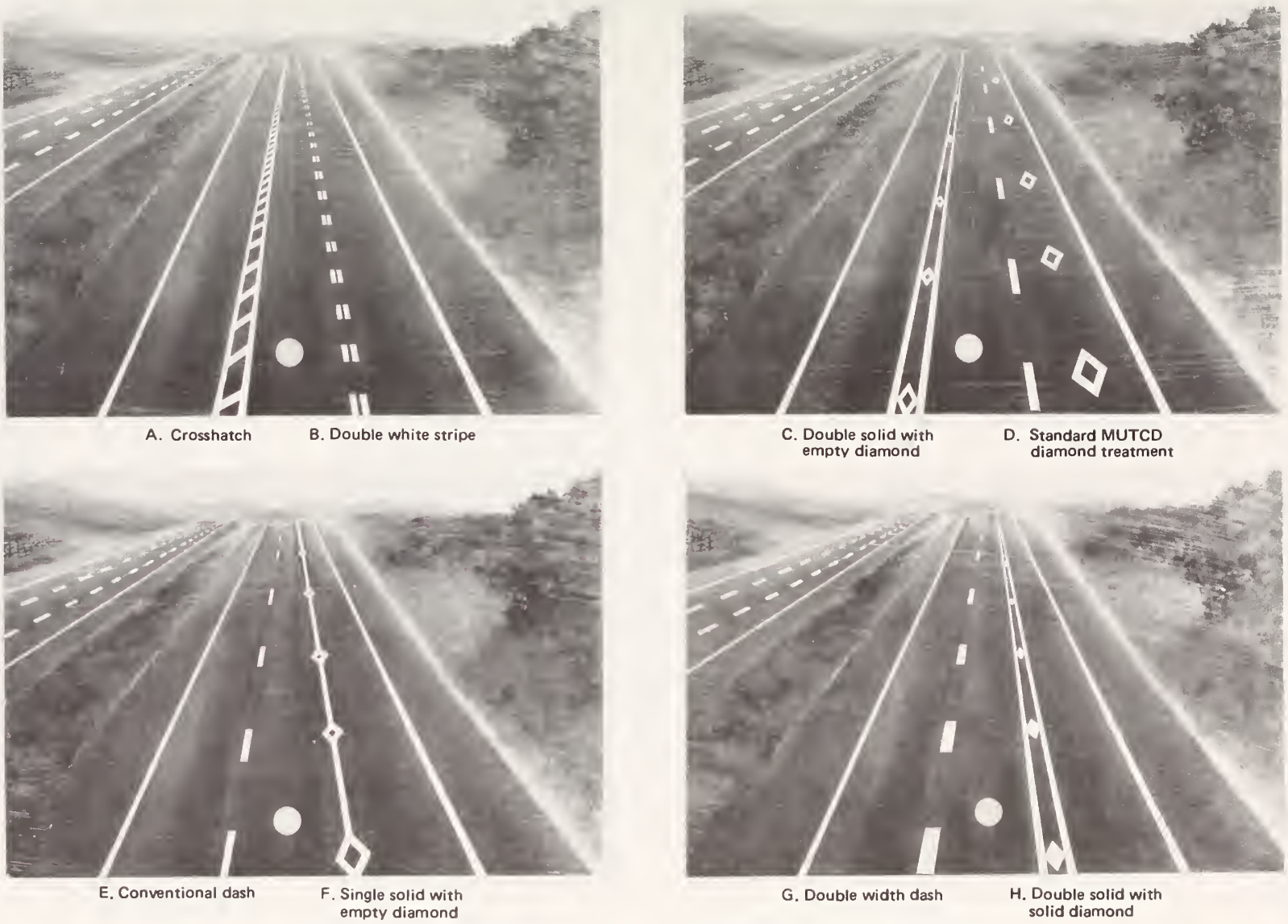

A. Crosshatch
B. Double white stripe
C. Double solid with empty diamond
D. Standard MUTCD diamond treatment
E. Conventional dash
F. Single solid with empty diamond
G. Double width dash
H. Double solid with solid diamond

Figure 19. Sample stimulus pictures for delineation design experiments.
(Originals in color)

(see instructions in Appendix C). Subjects then indicated on a response sheet (see Appendix C) whether they would go around the truck (included in the stimulus picture) in the center lane by using the left or right lane.

In addition to the paired comparison experiment, each treatment was shown alone. Subjects checked which of six driving behaviors was appropriate for that delineation treatment (see Appendix C for instructions and sample response sheets). Forty subjects (aged 18 to 62, male and female) from the State College, Pennsylvania area participated. Each experimental session of 153 paired comparison trials and 18 questionnaire trials lasted 30 to 40 minutes.

Results

Paired Comparison Data. Paired comparison data were first summarized in a table of proportions, and then traditional scale values were calculated (Guilford, 1954). Figure 20 illustrates the scale and where each treatment falls on the scale. Scale numbers are quite arbitrary, i.e., they could be transformed to all positive, negative, times 100, etc.; but the distances between values are meaningful. For example, a standard dash line (scale value $\simeq$ 1.3) is twice as permissive as a line of diamonds (scale value $\simeq$ .6).

Questionnaire Data. The responses to the questionnaires were tabulated by treatment. Figure 21 gives the resulting percent response. Since the six questionnaire alternatives for each treatment formed a loose scale or continuum ranging from open or general use, to assorted restrictions, to "I cannot use the lane," to "I don't know," a weighted mean was calculated for each treatment. Thus, the response alternative number (1,2,...6)

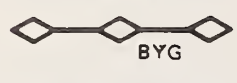
Questionnaire Rank	Paired Comparison Rank	Treatment and I.D. #		Paired Comparison Scale Value
				Permissive
2*	1*		(1)	1.3 1.2
4	2	WHITE	(2)	1.10
5	3	BLUE	(14)	1.00 .9
1	4	BYG	(13)	.8 .7
6.5	5		(10)	.6
3	6.5		(4,8)	
6.5	6.5			.5 .4 .3 .2 .1
9	8		(9)	
8	9		(3)	0
14	10		(5)	- .1
10	11	BYG	(17)	- .2
11	12	BLUE	(18)	- .3 - .4
12	13		(6)	- .5
17	14		(7)	- .6
13	15	BLUE	(16)	- .7
15	16	BYG	(15)	- .8
16	17		(12)	- .9 -1.0
18	18		(11)	-1.1 -1.2 -1.3
				Prohibitive

Spearman Rank Correlation:

$r_s = .93$

*1 = most permissive; 18 = most prohibitive

Figure 20. Paired comparison scale values, eighteen delineation treatments.

	Treatment	Response 1*	2	3	4	5	6
1		75	7	7	2	2	7
2		62	11	7	2	7	11
3		26	36	14	0	5	19
4		62	21	2.5	2.5	2.5	9.5
5		9.3	11.6	11.6	21	18.6	27.9
6		13.6	9.2	20.4	9.2	27.2	20.4
7		2	6	22	22	22	26
8		30.9	40.5	9.5	0	0	19.1
9		20	27.5	17.5	7.5	2.5	25
10		41.5	22	12.2	2.4	2.4	19.5
11		2.4	4.8	17.1	17.1	39	19.5
12		10	16	24	18	18	14
13		75	12.5	2.5	0	0	10
14		52	10.9	17.4	8.7	2.2	8.7
15		2.5	2.5	17.5	32.5	15	30
16		4.6	11.6	23.3	23.3	11.6	25.6
17		19	30.9	12	9.5	0	28.6
18		20.9	20.9	18.6	16.3	0	23.3

*See Appendix C for examples of the six responses.

Figure 21. Percent response to questions for each treatment.

was multiplied by the frequency. These numbers were summed across responses for each treatment and the total divided by N to give a weighted mean. The lower the weighted mean, the more permissive the meaning of the treatment. Finally, the treatments were ranked from most to least permissive. These ranks appear next to the paired comparison ranks in Figure 20. A Spearman rank correlation of $r_s = .93$ indicates that the results from the two different measurement methods are highly complementary.

Analysis

The impact of several design parameters of prohibitiveness-permissiveness are evident from the scaling. First, any pattern or design that has repeated openings in the design (e.g., dashes, skips) is clearly more permissive than treatments with a continuous or broken line. This appears to be a general design principle that is relatively unaffected by the specific pattern of symbology used.

Width of line appears to be relatively ineffectual. The double-width dashes (treatments 3, 13, and 14 in Figure 20) were less permissive than a standard dash, but clearly less prohibitive than any other treatment.

The impact was studied by including three treatments (numbers 2, 9, and 7 in Figure 20) in different colors: white, light blue, and bright yellow-green (BYG). Referring to the relative positions of the colored designs in Figure 20, two findings are evident. There is no consistent difference between light blue and BYG in treatment meaning. Colored treatments, compared to the white version, were consistently more prohibitive but by relatively small amounts. This suggests that color can readily be included in a design without drastically changing treatment prohibitiveness-permissiveness.

The questionnaire data supplement the paired comparison data in several ways. Any treatment with a skip was seen as "restricted to special vehicles" or "not to be used" by very small percentages of the respondents. All treatments with a solid or continuous line/pattern elicited a higher rate of "restricted, I cannot use" responses; however, a relatively high percentage (12 to 25%) of respondents thought the other side of the buffer zone could be used to stop for repairs. A much smaller percentage (2.5 to 17%) of respondents would stop on the other side of a dashed treatment. Further work on how drivers perceive where they can stop their vehicles is necessary before final design recommendations can be made.

Color had no strong impact on the meaning of the designs. Blue tended to be associated slightly more with a reserved or special-vehicles-only meaning, and BYG with "can cross for turns and exit ramps." Based on the paired comparison and questionnaire results, color appears to play a very secondary role in shaping subject responses.

An experiment on the I-95 priority lane in Miami (Courage et al., 1977) provides supporting evidence for the laboratory findings. Over a 2½-mile portion of the facility, a solid white lane line was used and then replaced with a standard dash. There was significantly greater weaving and higher lane violation rates for the dash compared to the solid line. This suggests that the differences found on the dash/solid dimension in the laboratory will generalize, at least to some degree, to an operational setting.

In that project four- and then eight-inch skip lines were used to separate the general lanes and priority lane over a 2½-mile section of the roadway. The three measures of effectiveness--weaving, violation rate, and travel time--showed no

differences between the two stripe width conditions. Given the consistent laboratory and operational experimental results, further investigation of stroke-width in delineation design does not appear fruitful. These findings do not fully explore the issue of total width; further study of this is reported in Experiment 2.

Conclusions

- The various delineation designs tested do vary in terms of the prohibitive-permissive dimension.
- Dash or skip designs are more permissive than continuous designs, regardless of symbology.
- Solid (or filled) diamonds appear more prohibitive than diamond outlines.
- Line stroke-width appears to have little impact on subject reactions to designs.
- Color tends to add prohibition to design meaning, but generally is a secondary determinant of subject response.
- The paired-comparison forced-choice and questionnaire techniques provide different types of information about delineation design and the data are highly complementary, e.g., $r_s = .93$.
- Several design characteristics must be further defined before design recommendations can be advanced. Included are: width, effect of spacing or density of symbols (ranges in crosshatch), weave section delineation and signing, and perception of where a vehicle can be stopped relative to the markings.

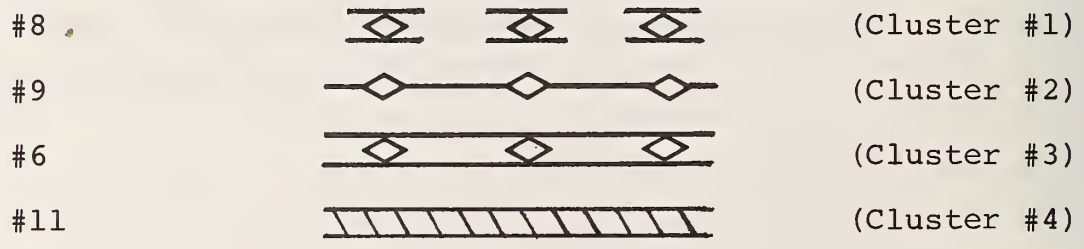
Experiment 2:
Width and Density of Design Elements

Purpose

Experiment 2 was committed to determining the effects of varying width and density of delineation design elements on driver perceptions of permissiveness-prohibitiveness.

Essentially, this is an examination of the effects of varying the horizontal and vertical image presented to the driver. The vertical factor may be called "stroke element density." This is the actual number of elements, either diamonds or crosshatch strokes, within any given line. This concept emerged out of the Experiment 1 data since a clustering of delineation treatments occurs (see Figure 22) according to varying degrees of what subjects perceive as a "wide thick look" versus a "thin sparse look." As shown in Figure 22, treatments 1, 2, 14, 13, 10, 4, and 8 are a cluster--a separated, thin look; 9, 3, 5, 17, and 18 are connected but still thin; 6, 7, 16, and 15 are wide and connected treatments; and finally, the crosshatch lines, treatments 12 and 11, are wide and strictly prohibitory--a very dense look.

Four treatments were selected for study of the width and density parameters, one from each of the above described clusters. These are the following:



Clusters	Paired Comparison Rank	Treatment and I.D. #	Comparison Scale Value
			Permissive
	1*	(1)	1.3
			1.2
1	2	WHITE (2)	1.10
Separated Thin Look	3	BLUE (14)	1.00
			.9
	4	BYG (13)	.8
			.7
	5	(10)	.6
	6.5	(4,8)	
	6.5		.5
			.4
			.3
			.2
			.1
2			
Connected Thin Look	8	(9)	
	9	(3)	0
	10	(5)	- .1
	11	BYG (17)	- .2
	12	BLUE (18)	- .3
			- .4
3	13	(6)	- .5
Connected Wide Look	14	(7)	- .6
	15	BLUE (16)	- .7
	16	BYG (15)	- .8
	17	(12)	- .9
4			-1.0
	18	(11)	-1.1
Connected, Wide, Dense, Strictly Prohibitive			-1.2
			-1.3
			Prohibitive

*1 = most permissive; 18 = most prohibitive.

Figure 22. Clusters of delineation designs according to scale values.

In attempting to design stimulus materials to study both width and density, it was determined that attempting to portray varying widths of one to three feet with an artist's drawing was not a perceptually good simulation of a driver's view, since the differences would be so obvious. The density issue, however, was very well suited to display on stimulus slides, similar to the ones used in Experiment 1. To reconcile this dilemma, it was decided to study the width issue in a more realistic, controlled field setting, and simultaneously, design a laboratory investigation of the density parameter using the slide technique. Thus, two experiments were performed instead of one, and these have been called Experiment 2: Field Component, and Experiment 2: Laboratory Component. The methodology, results, and analysis of each will be presented separately, then inputs to design from each follow.

Experiment 2:
Field Component

Method

The field component of Experiment 2 examined the width of the markings for each of the four configurations described above. For each design, widths of 1 foot, 2 feet, and 3 feet were paired against each other, yielding a total of twelve test pairs, three for each treatment. The matrix below shows the pairs tested.

Delineation Treatment and Code# / Pairs Tested	#6	#8	#9	#11
Set #1	1ft vs 2ft	1ft vs 2ft	1ft vs 2ft	1ft vs 2ft
Set #2	1ft vs 3ft	1ft vs 3ft	1ft vs 3ft	1ft vs 3ft
Set #3	2ft vs 3ft	2ft vs 3ft	2ft vs 3ft	2ft vs 3ft

The dimensions of each design are given in Table 20. The pair-comparison technique utilized in Experiment 1 was maintained here, in that subjects were forced to indicate which treatment of the two shown in any given pair they would sooner cross, given a blockage in their center lane of travel. The stimuli here, however, were actual delineation stripes laid out on closed sections of roadway. Subjects were driven through each of the twelve pairs and asked to indicate a "left" or "right" choice for each.

The pairs were laid out on closed sections of Routes 32 and 100 in Maryland, off of I-95 north of Washington, D.C. Here on these roadways, each pair of treatments was laid out using 3M company construction grade temporary white lane tape. The pairs were each 100 feet long and 12 feet apart, and each pair was separated by 400 to 500 feet of driving distance. Figure 23 shows some examples of these pairs as laid out on the roadways.

The twelve pairs were laid out in random order on three sections of roadway, and placement of any given treatment on the left or the right was also counterbalanced. Upon completion of this layout, the test course was ready to receive subjects.

The basic testing routine consisted of two parts: the experimental drive through the test course, and then the completion of the answer form containing other questions about the markings just seen. As a subject arrived at his appointed meeting station, he was greeted by an experimenter and ushered to ride as a passenger in the test car. The car used was a 1978 Plymouth Volare automatic, a standard size vehicle with ordinary viewing distance and height for most drivers. The subject was briefed concerning his task by being told that, as he was driven through each test pair, to indicate on his answer

Table 20

Width and Design Dimensions
for Each Treatment

Design	Buffer Width	Stroke Width	Diamond Length To Width	Spacing Of Design Elements
	1ft	2"	3:1	5 diamonds 20/25ft apart
	2ft	4"	3:1	5 diamonds 18/20ft apart
	3ft	6"	3:1	5 diamonds 15/17ft apart
	1ft	2"	——	2" crosshatch strokes @ 45° angle, 5ft apart
	2ft	4"	——	4" crosshatch strokes @ 45° angle, 5ft apart
	3ft	6"	——	6" crosshatch strokes @ 45° angle, 5ft apart

Connected diamonds - 3 ft. vs. 2 ft.

Diamonds embedded in solid lines - 2 ft. vs. 3 ft.

Crosshatch - 3 ft. vs. 2 ft.

Diamond/Dash treatment - 1 ft. vs. 3 ft.

Figure 23. Sample stimulus pairs of varying line widths laid out on closed sections of roadway.

sheet whether he would sooner cross the line to the left or the line to the right. This ensued for all twelve pairs. Appendix C contains a copy of instructions read to the subject, and a copy of page 1 of the answer sheet. Driving speed through the test pairs was 35 to 40 mph, giving an exposure of several seconds for each in a dynamic driving mode.

After the drive-through, subjects were returned to their point of origin, and filled out the remainder of the test sheet. The remainder of the test sheet showed drawings of each of the four buffer designs that they had just seen, and subjects checked which of six driving behaviors were appropriate for that buffer zone treatment. These behaviors were the same six used to evaluate the treatments in Experiment 1. Also, subjects were asked to rank each treatment, from 1 to 4, in terms of which best showed a meaning of special use lane (1) to which least conveyed this meaning (4). Copies of the response sheets on which this data were recorded are found in Appendix C.

Thirty-four licensed drivers participated in this study, 17 males and 17 females, ranging in age from 17 to 65. Seventeen were under 30, and 17 were over 30. These were drawn by various means of publicity throughout the Baltimore-Columbia, Maryland, area since this was convenient to the location of the test site, but also since it was felt that these drivers would be naive of SULs with the diamond symbol. In fact, demographic data taken from the subjects confirmed this: 79% indicated that they had never driven in or seen a bus/carpool lane. When asked whether or not any had ever seen the diamond symbol used on a roadway or road sign, over half (64%) reported that they had, yet further inquiry revealed that they were thinking of the diamond <u>shape</u> of advisory signs, <u>not</u> the MUTCD diamond.

Results

The paired comparison data were summarized in four small tables of proportions, one for each delineation treatment, then traditional scale values were calculated. Figure 24 diagrams the scale values obtained for each of the four designs. The total distance between widths, even in the most separated condition--the crosshatch design--is not a great distance, compared to the wide scale obtained in Experiment 1. Simple inspection also reveals almost total random assignment among widths throughout the scale. So the 1-foot, 2-foot, and 3-foot widths have essentially the same effects.

The data from the questionnaires replicate quite well that obtained in Experiment 1. Table 21 shows the tabulation of responses by each of the four treatments. As indicated in the Experiment 1 data, the six questionnaire responses form a loose scale ranging from open, permissive connotations to assorted restrictions ending with "keep out" or "I don't know." The response alternative number (1, 2,...6) is multiplied by the response frequency, summed for each row, and divided by N to yield a weighted mean. This indicates a ranking of permissiveness since the lower the weighted mean, the more permissive the meaning of the treatment. Thus, the dash-diamond treatment is more permissive, then the connected diamonds, followed by the crosshatch and solid lines, with embedded diamonds connoting a prohibitive image.

A final task for the test subjects was to rank order the four design treatments from "best" to "worst" (1 to 4), given that they are used to delineate a special usage lane (see instructions and data sheet, Appendix C). In this case, the frequencies of selection for each rank per treatment are tabulated. Then weighted rank sums are computed (rank is multiplied

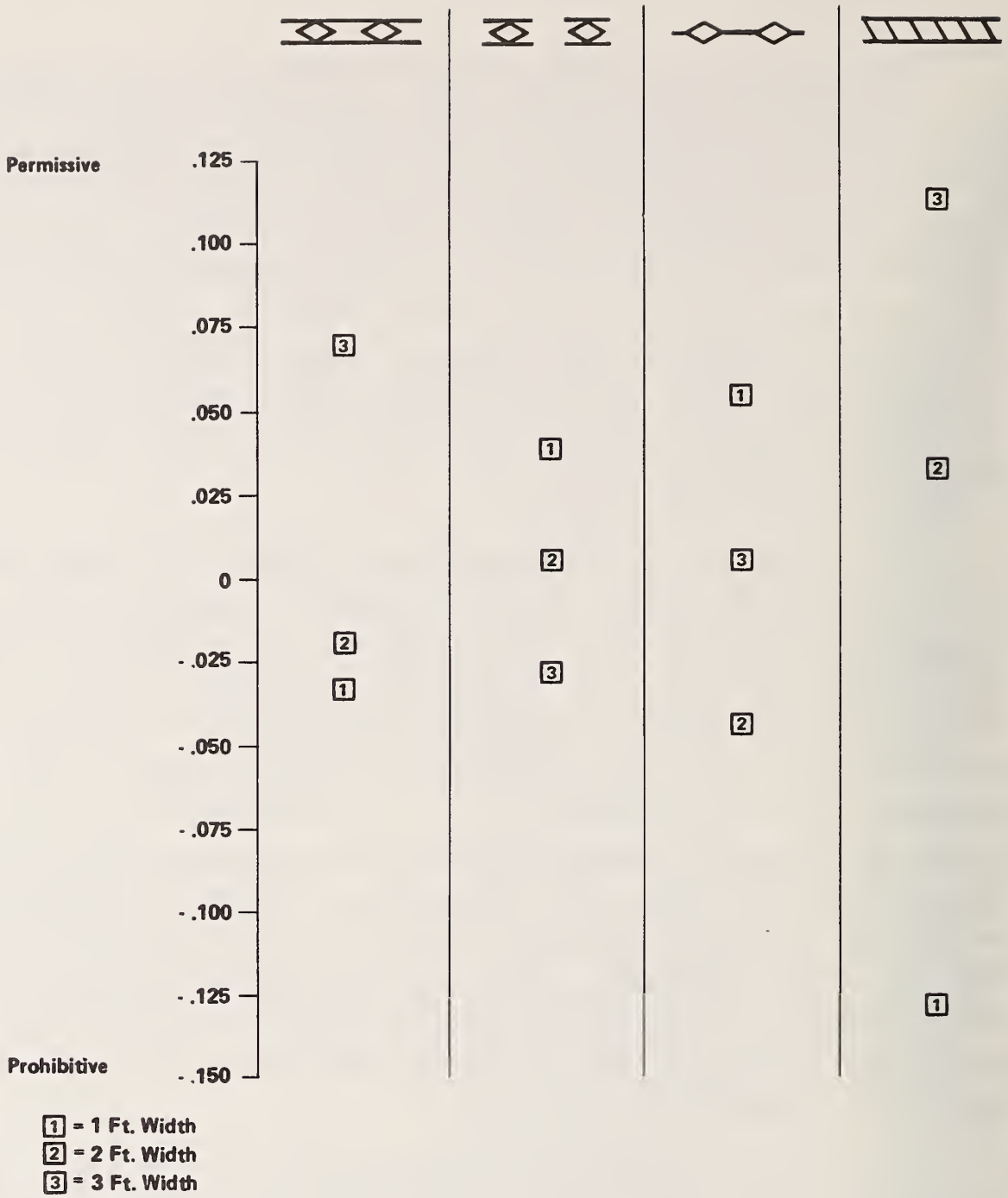


Figure 24. Paired comparison scale values (field component).

Table 21

Frequency of Responses for Each of Six Driving Behaviors for Four Delineation Treatments

Response Option / Treatment	1 Pass & Travel Freely	2 Turns & Exits Only	3 Repair/ Emergency Lane	4 Special Use Lane	5 Do Not Use It	6 I Don't Know	Weighted Mean
	6	4	8	6	0	14	24.3
	18	3	5	3	1	9	18.3
	1	8	7	8	2	9	22.3
	2	7	9	6	8	6	23.8

by frequency, then summed for each treatment), which gives an overall ranking to each design. Table 22 is the table of ranks and the resulting ranking of the four designs based on these data.

Table 22

Matrix of Frequencies by Rank
for Each of Four Delineation Treatments

Rank					
"Best"	1	10	14	4	2
	2	14	5	7	4
	3	6	3	9	12
"Worst"	4	0	8	9	12
Weighted Sum*		56	65	81	94

*Lowest number is closest to "Best"

Analysis

Delineation design width appears to be relatively ineffective on permissive-prohibitive connotation. The cost-effective, space saving 1-foot striping is certainly acceptable for use. In fact, avoidance of the wider widths seems desirable since these may have a tendency to take on a shoulder or break-down area meaning, especially in the crosshatch design.

The ranking method of assessing the design meaning clearly corroborates both the paired comparison and questionnaire findings. The design with a dash pattern was judged least effective in conveying the meaning of special or restricted use.

The double solid line with diamonds and with crosshatch were very close together. A close look at the crosshatch frequencies reveals that many observers ranked this number one, but a surprisingly high number ranked it number four. This bimodal distribution suggests the crosshatch may be so strongly prohibitive that the connotation of "specialness" is masked for almost one-third of the subject drivers. Many drivers appeared more comfortable with a "diamond look" to mean special, and felt that they might belong in the lane, if only there were some signs or other explanations as to just what the diamonds meant. Many drivers verbalized this thought unsolicited during the test drive.

Conclusions

- There is no appreciable difference in the prohibitory effects of 1-foot, 2-foot, or 3-foot widths for the four delineation treatments tested.
- The dash/diamond treatment is the most permissive in terms of driver tendency to cross. This replicates findings from Experiment 1, revealing the potency of a skip design to promote crossover.
- Striping with diamonds connected by a single line or with diamonds embedded between two solid lines is seen as associated with a special usage lane.
- The association of the diamond with special usage properties is apparently diminished somewhat when part of a skip design.
- The crosshatch "ladder" type striping is again most prohibitive in terms of driver tendency to cross. This also replicates the findings of Experiment 1.

- There is some divergence among various observers as to whether the potent prohibitory effect of the crosshatch design is necessarily associated with the concept of the special usage lane. Further investigation of this is indicated.

Experiment 2: Laboratory Component

Purpose

The laboratory component of Experiment 2 was concerned with determining the effects of stroke element density, i.e., whether the number of these diamond or crossline elements within a given area would impact on driver decision to crossover.

Method

The pair-comparison technique employed previously was again exercised here, using the slide presentation technique as in Experiment 1. Eighteen treatments were generated using the four basic designs (see preceding discussion--Field Component Study). The ratio of elements to gap was tested at three levels, i.e., for every given vertical element space, a 2-, 4-, or 6-gap length was used, simulating 12-, 24-, and 36-foot spacing. Also addressed was the impact of the unassigned colors, bright yellow-green and light blue, affecting the prohibitory effects of the potent crosshatch "ladder" design. Figure 25 presents a list of the eighteen treatments tested. Examples of the stimulus slides presented are given in Figure 26. The testing routine was a duplicate of that in Experiment 1: A total of 153 stimulus slides were presented in random order, and subjects checked on their response sheet "left" or "right" to indicate which line they would sooner cross to bypass a center lane blockage. Subjects also filled out questionnaire data, rating and ranking

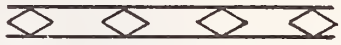
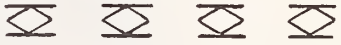
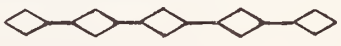
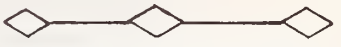
	Design	Density Elements to Gap	Appearance
1.	Solid Lines with Embedded Diamonds	2:1	
2.	Solid Lines with Embedded Diamonds	4:1	
3.	Solid Lines with Embedded Diamonds	6:1	
4.	Dashed Lines with Diamonds	2:1	
5.	Dashed Lines with Diamonds	4:1	
6.	Dashed Lines with Diamond	6:1	
7.	Diamonds Connected with Single Line	2:1	
8.	Diamonds Connected with Single Line	4:1	
9.	Diamonds Connected with Single Line	6:1	
10.	Diagonal Crosshatch	2:1	
11.	Diagonal Crosshatch	4:1	
12.	Diagonal Crosshatch	6:1	
13.	Number 10 in Bright Yellow-Green (BYG)		
14.	Number 11 in BYG		
15.	Number 12 in BYG		
16.	Number 10 in Light Blue		
17.	Number 11 in Light Blue		
18.	Number 12 in Light Blue		

Figure 25. Delineation designs tested, varying stroke element density.

Crosshatch vs. Diamond Dash - Widest gaps

Crosshatch (mid-size gap) vs. Connected Diamond - Shortest gap

Diamonds in solid line (widest gap) vs. Crosshatch (midsize gap)

Crosshatch - Widest gap vs. Shortest gap

Figure 26. Sample stimulus pictures for stroke element density delineation designs (originals in color).

the four delineation designs they had just seen, using the same questions as in the preceding field component study. (Copies of instructions and response forms are found in Appendix C.)

Twenty-eight subjects participated in the study, 17 males and 11 females ranging in age from 18 to 59 years old. They were drawn from the State College, Pennsylvania area. Demographic data obtained from these participants revealed that they were generally naive of carpool/buslane operations and also of the diamond symbol's association with such lanes.

Results

Paired comparison data were first summarized in a table of proportions and subsequently transformed to traditional scale values for each of the eighteen treatments. Figure 27 is a representation of the scale and where each of the treatments falls within it. The scale ranges from permissive, promoting crossover; to very prohibitive, discouraging crossover. Table 23 presents tabulations of the questionnaire data for each of the four treatment designs. Frequencies for the six questionnaire responses forming the loose scale from permissive to prohibitive to "I don't know" were again transformed into weighted means for each design. The ranking data for each design is given in Table 24. This shows the frequencies of assignments to each rank for each design, then the scaling, best to worst, by computation of weighted sums. (This procedure was described in the preceding field component study.)

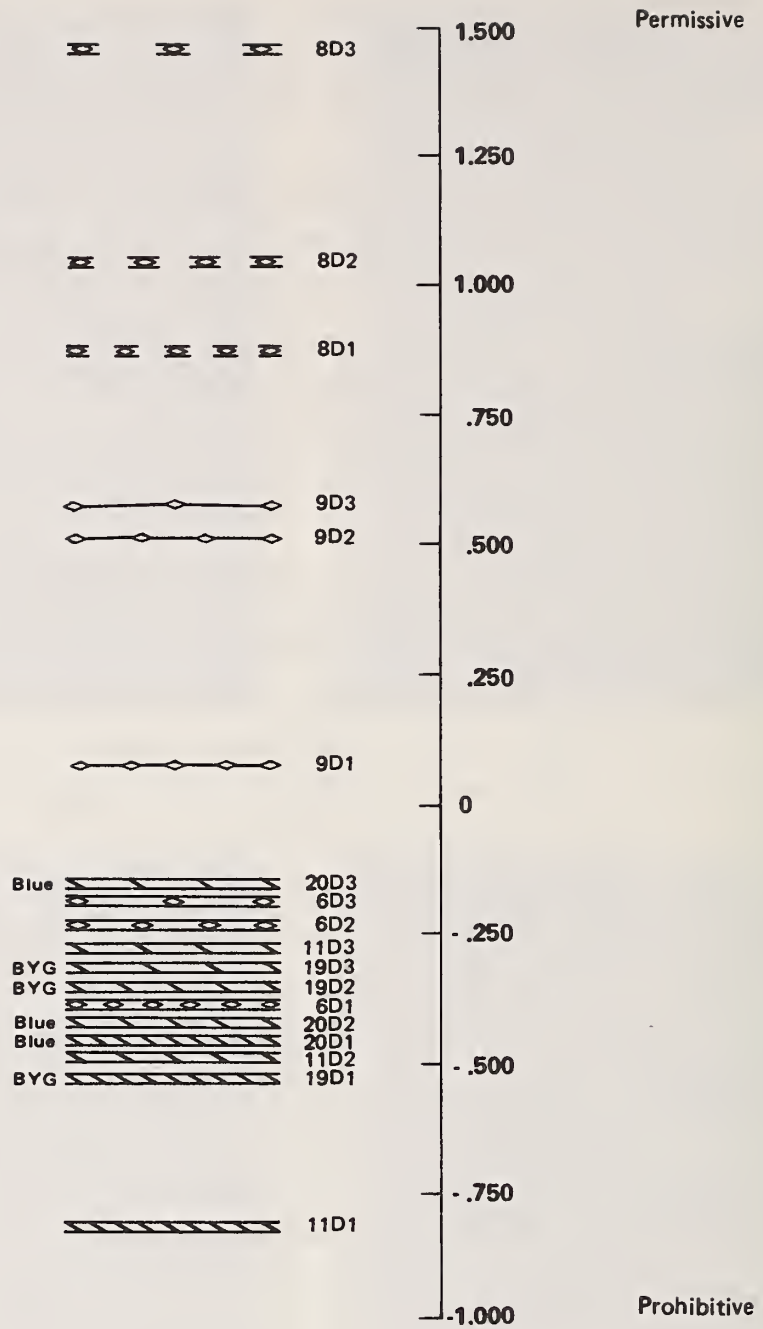


Figure 27. Paired comparison scale values for each of eighteen delineation treatments.

Table 23

Frequency of Responses for Each of Six Driving Behaviors for Four Delineation Treatments

Response Option / Treatment	1 Pass & Travel Freely	2 Turns & Exits Only	3 Repair/ Emergency Lane	4 Special Use Lane	5 Do Not Use It	6 I Don't Know	Weighted Mean
	1	9	6	8	4	4	18.8
	14	5	4	1	0	7	13.6
	7	9	6	4	0	4	13.8
	0	1	8	3	13	4	21.1

Table 24

Matrix of Frequencies Ranking Each of Four Delineation Treatments

Rank				
"Best" 1	5	2	1	1
2	14	4	6	1
3	4	0	15	10
"Worst" 4	1	3	6	17
Weighted Sum*	53	41	82	100

*Lowest number is closest to "Best"

Analysis

Several conclusions are clearly evident from the scale data. First, the dash design with the embedded diamonds is most permissive, followed by the diamonds connected by a single line. Both are characterized by the thin look and a broken appearance, and all six of these treatments, regardless of stroke element (diamond) density, are above the zero point, indicating permissiveness. The crosshatch treatments of varying density and color, as well as the diamonds embedded between two solid lines, all cluster below zero, acting as prohibitory agents to lane change. This is a direct validation of previous findings.

Second, within the scale separations for permissiveness-prohibitiveness by design, each design becomes more prohibitive within its own space with increasing density of stroke elements. A look at the scale shows this, in that each design descends from density 3, to 2, to 1 down the scale toward the prohibitive end.

Thus, the most open dash treatment (the diamond dash combination) is at the very top, and the tightly spaced white crosshatch ladder design is at the very bottom, well separated from the initial prohibitive cluster.

The third conclusion here regards the impact of color on the crosshatch designs. No appreciable effect or advantage can be seen in the use of color; it seems to promote some relative indecision, but generally does not impact on perceptions of permissiveness. Its merit apparently must lie in being a cue to associate with other available information, such as on signing. Several subjects commented on this point.

Rating and ranking questionnaire data showed the following. Most permissive is again the diamond dash (13.6), followed by the diamonds connected by the single line (13.8). More prohibitive is the embedded diamonds within two solid lines (18.8), and lastly and most restrictive is the crosshatch design (21.1). All treatments with solid lines elicit a kind of restrictive meaning. The diamond options are more associated with a special usage lane, except for the diamond/dash treatment. The dash presentation again diminishes the effects of the associative meaning of symbols and conveys the more important factor--namely, "the line is dashed, so I can cross it." The crosshatch image is strongly prohibitive. No respondents elected the pass and travel option, and most (46%) characterized it as "do not use." All of the connected treaments, especially the crosshatch, find a quarter to a third of the subjects indicating that the lane could be for emergency repair. This factor deserves further study.

The crosshatch design was ranked best of the four design alternatives, with the solid double lines plus diamonds a clear second. This is the reverse of the rankings from the field

study. A question remains: Is the switch in position due to chance fluctuation, or is it related to real life (full size and perspective) experience versus exposure to artist rendition/ projected image stimuli? Only further empirical work can provide the answer.

The single solid line with diamonds was ranked third and the dash pattern was ranked least effective in conveying the meaning of restricted or special use.

Conclusions

- The four buffer designs are affected by the density of stroke elements in that the more elements per gap width, the more prohibitive the line.
- The skip then thin look designs remain the most permissive to drivers, regardless of actual symbology.
- The solid connected delineation lines, with embedded diamonds or crosshatch lines, are powerful prohibitors of lane change.
- Use of color upon the stroke lines does not appreciably affect the prohibitive-permissive aspects but could trigger associative meanings if accompanied by signing. Further test of this is needed.
- Questionnaire and ranking data on the four designs tested correlates well with the results from the pair comparison trials, and with the previous experimental studies.
- Further investigation of the crosshatch design must ensue in a field setting in order to monitor the true potency of its prohibitory effects and its potential for association with the special usage lane meaning.

Experiment 3:
Field Feasibility Study

Purpose

The objective of Experiment 3 was a pilot field test of some of the findings from Experiments 1 and 2 regarding prohibitive-permissive striping.

Discussion

Data from Experiments 1 and 2 on the various types of delineation treatments demonstrated the power of certain configurations to exert permissive or prohibitory effects on lane change behavior. The next step was to apply these findings in a real-world setting in order to determine their actual potency as a "buffer" between a concurrent flow bus lane and the regular traffic lanes. It seemed intuitively clear that to impose designated access/egress points along a freeway HOV lane, via variations in the prohibitive-permissive layout of buffer striping, was not safe since crossovers from the HOV lane into the general lanes must be a matter of discretion according to available gaps. Testing of this buffer concept in an arterial setting was considered, however.

It seemed reasonable that installation of a prohibitive buffer would generally discourage violators. More pointedly, allowing a more permissive buffer near certain intersections might induce legitimate right-turning vehicles to make their entry within designated limits near the turning point, rather than making their entry into the HOV lane as a violator, blocks in advance. The general idea for the buffer with right turn areas is as portrayed in Figure 28.

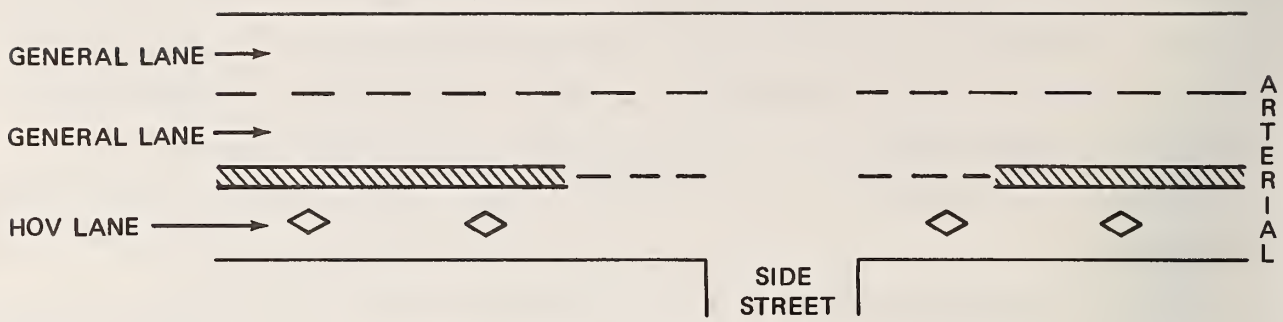


Figure 28. HOV lane with buffer strip becoming permissive at right-turn areas around urban intersection.

The steps in determining the feasibility of applying and measuring the effects of such a proposed buffer installation were observational in nature and consisted of the following:

1. Determine whether right-turning activity at candidate intersections is sufficient to measure changes before and after installation of buffer.

2. Observe traffic characteristics at the same sites to determine any problems/needs affecting installation of buffer treatments and evaluation data collection.

Method

Assessment of right-turning vehicle activity and traffic characteristics consisted of the following procedure:

- Identify candidate intersections for study.
- Observe traffic behavior during designated peak hours when HOV lane is operating.
- Analyze and discuss observations.

The intersections chosen for study were located along two corridors containing HOV lanes, one in Baltimore, Maryland; and the other in Washington, D.C. Both were among the many sites inventoried in the Task 1 site inventory.

The Baltimore site was a 2-mile section on North Charles Street in Baltimore city between Madison and 26th Streets. This is a four-lane, one-way facility. The right curb lane operates as the concurrent flow HOV lane from 3:30 to 6:30 p.m., Monday through Friday. A particular appeal of this site was the several sets of one-way, east-west couplets crossing Charles Street where right turns would be possible at some intersections but not at others. Therefore, the desired behavior would be entry for right-turn-only in those certain blocks where the one-way street was to the right (eastbound). Also, the facility has no current striping, pavement diamonds, or signing containing the diamond symbol. In fact, the signing informing road users of the pertinent information regarding the bus lane is very minimal and at times obscure.

The Washington, D.C., site was along a 3.5-mile section of Connecticut Avenue, N.W., between Chevy Chase Circle and Calvert Street. This operates as a dual facility, in that most sections are six lanes wide with the middle lane reversing at peak hours. Thus, four lanes proceed southbound to the CBD in the morning, and four lanes operate northbound to the suburbs in the afternoon. The HOV lanes are the right curb lanes. They are meant for buses, taxis with fares, and bicycles during the rush hours (7 to 9 a.m.

and 4 to 6 p.m.). With a few exceptions, the signing and delineation are standard MUTCD with the diamond symbol on the signs and pavement diamonds in the center of the HOV lanes. Standard white skip lines separate the lane from the general lanes.

So here were located two very different HOV lanes in two neighboring cities, close enough for logistical convenience but very different in information displays and layout. Presumably, these differences would provide a variety of user behaviors to allow a rich data gathering operation.

To identify candidate intersections for study along these facilities, respective local transit and traffic authorities were contacted and asked for traffic count and turning volumes, if available. Both cities were responsive to this. It was immediately obvious from these counts that sufficient volumes exist to warrant on-site observations.

Traffic operations were observed at various intersections by visiting the sites several times during the peak hours and performing drive-throughs. Then a plan for a closer picture of actual daily traffic behavior was conceived. Observers walked along various sections of the sites and selected vantage points along the streets and atop adjoining buildings from which to view right turns and violators during the entire peak period. Minolta movie cameras were mounted atop two buildings along Charles Street, while observers at both street- and roof-level took manual counts of the right-turning vehicles' activities. The films provided an overall record of traffic volumes, traffic flow, number of buses, etc.; the manual counts detailed vehicle entries into the bus lane by specified points (i.e., mid-block, one block ahead, just in advance of the turn, etc.).

Appendix C contains a copy of the form used to collect the data. These data were taken in 15-minute intervals for the duration of the peak period on Charles Street in Baltimore, recording right turns onto Biddle Street (west), and from Chase Street onto Charles Street. The numbers recorded are very much representative of those obtained at other intersections on the facility, and on the Connecticut Avenue corridor in Washington. Violators in the HOV lane are determined by adding the total of column 1 (those who entered the HOV lane one block in advance--thoroughfare section) to the total of column 2 (those who entered the HOV lane within the turning block), and from this subtracting the total right turns--column 3. Thus, any non-HOV that was in the lane and did not turn right was defined as a violator.

The side street activity is very pointed in that right-turners from the side street nearly always had the option to turn onto the main corridor by entering either the HOV lane or a general lane. By this, violator behavior could easily be recorded for a field test of a buffer.

Results

Two trends are immediately apparent from the data. First, right-turning activity is significant but not high enough to create excessive demands on data collection. Second, the number of violators in the HOV lane is also significant enough (about 100 per hour) to provide monitoring of any before-after effects associated with installation of the buffer.

Other factors uncovered during these observational ventures were not as promising, however. Bus counts from the film data showed a high volume (over 50 per hour) of buses queuing at intersections, interfering with some right-turners. Also, it is not feasible to actually track true violators, since in Baltimore

vehicles can legally enter the HOV lane two blocks in advance of the intended right turn. Thus, the non-HOV spotted in the HOV lane would have to be tracked over three blocks to be identified as a true violator. Essentially the same situation prevails in Washington, since the blocks are much longer. Even with the capability of tracking and recording vehicles for several blocks to measure the impact of the buffer, this would mean laying the lane tape throughout the area to be considered. Logistically and economically, the taping and tracking activities would exceed the scope of the effort allowed in this pre-field task. The high volume of buses queuing in the lanes, coupled with the logistic and economic difficulties of implementing the right turn buffer, were the significant factors that halted the deployment of the study.

Analysis

The observational efforts described above were not, however, unrewarding. Even though the intended intersection experiment with the better striping did not materialize, two important by-products of the observational activity were realized.

First, in the process of formulating an overview of the traffic operations of the various sites, a wealth of field experience was gained. Contacting local officials and thus establishing liaisons was invaluable. Performing the many drive-throughs and walk-throughs about the various sites involved locating vantage points, setting up photographic equipment, establishing counting stations, and relating to local persons to obtain permission to use parts of buildings as perches. These types of experiences and activities were a propitious and well-timed prelude to the full field studies to be performed next.

Second, the various field activities and encounters involved interaction with a substantial number of people. This provided many unsolicited reactions and responses to the HOV lane, its operations, and this type of facility in general. For example, counters stationed at various points on the street generated much curiosity from citizens; many enlightening, brief conversations regarding the observer's purpose were noted. A similar finding of curiosity was obtained from those contacted seeking use of their buildings or sections thereof for vantage and viewing points.

From this second by-product--which might be called unsolicited survey data--some general recurring themes emerged. In Baltimore, where the signing for the bus lane is minimal and the delineation absent, the majority of those spoken to did not even realize the presence of an HOV lane on the Charles Street facility (2 to 1 did not know). In Washington, however, the trend was somewhat reversed (3 to 1 aware of the HOV lane); this is understandable since the MUTCD signing and delineation standards prevail. In each city most were very familiar with the respective facilities, driving along it at least once a week or more and many on a daily basis. As it was revealed that the field observers were simply monitoring traffic operations of the HOV, many passers-by at first did not realize exactly what was meant by the concept "special usage lane." In Baltimore, some were convinced that the special lane was a left lane drop onto nearby I-83 North; while in Washington, considerable mention of the reversible lanes in the center of the street was made. With a little clarification, however, most acknowledged the HOV lane concept and were about 5 to 1 in favor of it and its continued operation, this in both cities. This information was volunteered in some cases, while in the same breath some admitted that there were or would be flagrant violators of the lane since it was

minimally enforced. In general, in these two cities the public seemed favorably disposed to the HOV lane, as long as buses in fact stayed in them and out of the way of the general lanes.

A final word. A few curious individuals find traffic researchers an open forum to voice their complaints about streets and highways. This series of observations was no exception. The observers and counters heard many comments about potholes and street sweepers bogging down traffic. In general, though, the local citizenry was very cooperative, curiously interested, and convivial, encouraged that an interest was being taken in a facility close to their homes.

Conclusions

- Violation rates on concurrent flow bus lanes may be affected by high bus and right turning vehicle volumes.
- Measures of effectiveness in the field seem well suited to data collection via time-lapse photography, with hand counts to supplement.
- "Weaving sections" or prohibitive/permissive buffer stripings are not an effective control device due to confounding safety problems and high lane occupancy by buses.
- Citizens are favorably disposed toward bus lane operations in theory--disposition in actual driving practice must be realized in full field effort.

Experiment 4:
Use of Positive Delineators; Association and Placement of Signing with Markings

Purpose

The final effort of Task 3 broke down into four small studies to resolve issues related to delineation design raised from the previous studies:

Issue #1: The use of cones, the "dashed-ladder" design, and parking stalls as impacting upon the identification of the bus lane.

Issue #2: The perception of various delineation designs as a shoulder or breakdown zone.

Issue #3: The association of candidate HOV signing with certain delineation designs.

Issue #4: The number and placement of HOV signs along a designated HOV lane.

The previous experiments in this task have identified and clustered delineation treatments by permissive/prohibitive parameters. It was revealed that the crosshatch or "ladder" design consistently elicits a very prohibitive effect on lane crossing behavior. At the same time, it was established that any delineation design portrayed in a skip fashion--that is, dashes with gaps regardless of design element configuration--promoted lane entry.

The first issue arose as: Would not the prohibitive "ladder" design become a permissive one if portrayed as a kind of skip- or dashed-ladder, having actual gaps between sections of its layout? This would be an effective delineator throughout a fairly long stretch of an HOV lane where variations in permissiveness/prohibitiveness are desirable for any given reason. Concurrent

with this issue was the need to examine the prohibitive/permissive aspects and perceptions of orange cones placed along the edge of the HOV lane, and the effect of a reversion of the HOV lane to a parking lane during off-peak hours.

In ferreting out inherent prohibitive/permissive connotations for these various designs, the second issue of importance was: Does a strongly prohibitive design at the same time somehow invite crossover if a breakdown/shoulder area is needed? If a design discourages lane entry for free travel, might it not come to be viewed as a safe stopping area for pull-overs and repairs?

Issue three was concerned with the question: Would the driver associate the lane marking on the road with a symbolic representation of this marking on a sign? The experiments previously discussed have not overtly dealt with the markings as relating to the need for further information. Subjects have said in previous studies that the markings provoked them to seek some meaning via a sign. So a task showing the marking, then showing a sign with that marking, was devised in order to evaluate the transfer, if any.

The final issue attacked in the delineation studies was designed to relate sign placement to the physical lane markings. The questions addressed relate to zones of information need: before the lane begins, lane entrance, and throughout the lane. This was devised to measure where the first sign might be placed and whether or not a great number of succeeding signs should follow.

Each issue described above was investigated via a laboratory study technique using stimuli simulating the driving situation. The first three involved a slide presentation technique, while

the final one was a paper-and-pencil task. Specifics for each are described below, followed by the basic findings from each.

Study 1

Method. The paired comparison technique used in Experiments 1 and 2 was well suited to evaluate the "ladder-dash" concept, cone usage, diamond lane/parking lane, and overall perceptions of combinations of these elements in conjunction with the HOV lane diamond symbol. The nature of these myriad elements was not well suited to layout on the highway background, however. Therefore, it was decided to employ the pair comparison technique to assess effects of all the given elements, but overlaid onto an urban arterial setting.

An artist's rendering of an urban arterial was created. Figure 29 shows a black and white photograph of this scene (substantially reduced). Overlaid onto this painting were the various delineation treatments to be evaluated. Figure 30 is a list of the treatments and a sketch of each. Note that the treatments represent a kind of progressive order, first A and B are cones alone, then C incorporates the diamond symbol, while D incorporates the ladder. E, then, is a combination of cones, ladder, and diamond. Treatment F starts a new progression, beginning with the ladder alone, and G is the ladder and diamond. H is the standard MUTCD diamond lane with regular skip line. Treatment I is the third permutation, the ladder-dash concept, with J adding the diamond. The final element is treatment L, wherein a parking lane with parking stalls is also the diamond HOV lane. A distractor element, K, reversible lane dashed, was included to offset some learning effects that might occur related to the diamond treatments.

Figure 29. Photo-reduced copy of arterial background setting (original in color).

Treatment	Description	Appearance
A	Post Cones	
B	Regular Cones	
C	Cones & Diamonds	
D	Cones & Ladder	
E	Cones/Ladder/Diamonds	
F	Ladder	
G	Ladder & Diamonds	
H	MUTCD Diamond Lane	
I	Ladder Dash	
J	Ladder Dash & Diamonds	
K	Reversible Lane Dashes	
L	Parking Stalls & Diamonds	

Figure 30. Delineation treatments for Experiment 3, Study 1

Each treatment was paired against every other treatment, randomly placed on the left lane or the right lane, yielding 66 pairs. 35mm slides were taken of each pair. These were shown in random order via a tachistoscope projection device that controlled stimulus exposure duration (1 second) and interstimulus interval (5 seconds). Figure 31 shows four examples of stimulus slides presented.

Two groups of subjects viewed the 66 stimulus slides. Group 1 was instructed to imagine that they were bus drivers seeking a high occupancy vehicle reserved lane, and to indicate "Left" or "Right" for each slide to record their choice. Group 2 was to imagine that they were simply drivers of single vehicles, driving down the center lane seeking a free-travel permissive lane to the left or right if they were forced to vacate the center. (See instructions and response forms in Appendix C.)

The subjects were 34 persons drawn from the Baltimore metropolitan area, 19 males and 15 females, ranging in age from 16 to 69. Nineteen were over 30, and 15 were under 30 years old. Group 1 (bus-driver scenario) consisted of 18 subjects and Group 2 (non-bus scenario) consisted of 16 subjects. Of the total group, 77% indicated that they were unfamiliar with bus/carpool lanes and their operations.

The two-group design yields two sets of lane choice data, one for the bus drivers, one for the non-bus drivers. Each set was reduced to proportions selecting one treatment over another, and then traditional scale values were calculated.

Results. Figure 32 diagrams the scale values obtained for each of the 12 delineation schemes. The bus driver group's choices fall on a scale ranging from perceptions that a particular

Captions

1. Ladder (F) vs. Ladder-dash with diamonds (J)
2. Ladder & cones (D) vs. Cones only (B)
3. Cones & diamonds (C) vs. Parking stalls & diamonds (L)
4. Cones (B) vs. MUTCD diamond lane (H)

Figure 31. Examples of stimulus slides for Experiment 4, Study 1

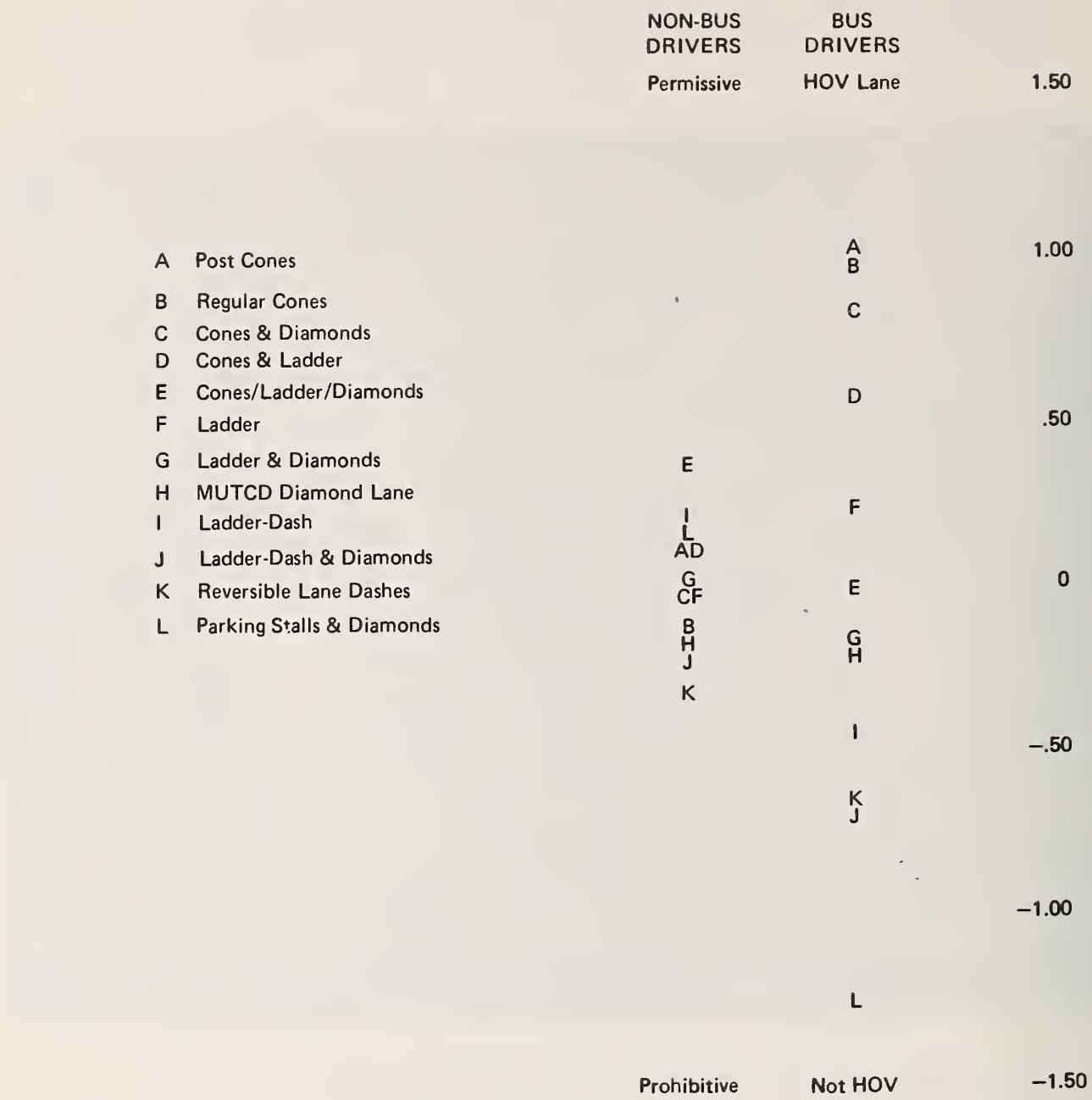


Figure 32. Scale values for Experiment 4, Study 1.

design represents an HOV lane, to perceiving that it does not. The non-bus group's selections fall out on a simple permissive/prohibitive scale, indicating which designs promote or prohibit entry into the lane.

Analysis. For the bus driver scale, subjects perceive treatments with the orange cones and the ladder by itself as best portraying a bus lane (treatments A, B, C, D, E, and F all at or above the zero point). Combinations with the ladder (but no cones) and in a dash form are not recognized as an HOV lane (treatments G, H, I, J, K, and L). The absolute bottom scale value is the parking lane/diamond lane (treatment L). Apparently, the look of parking stalls completely overwhelms the concept of a priority lane. The HOV lane concept is evidently lost to any skip or dash treatments, even the ladder-dash. The ladder alone does emerge as a possible HOV delineator. This confirms previous data from Experiments 1 and 2, since the ladder acts as a strong prohibitor and is apparently perceived by some as a good candidate for an HOV lane marking. The correct treatments quite strongly delineate a reserved, special lane for the bus driver group. Thus, their raised appearance and physical presence counteract the fact that they are spaced apart.

The permissive/prohibitive scale of values generated by the non-bus group is only interpretable as representing choices hovering around chance frequencies. Most treatments cluster around the zero point. This is a significant finding given the strong delineating nature of the elements tested since cones and ladder striping seem to spark confusion just by themselves, yet when given a scenario as for the bus driver group, fall out nicely on the bus driver scale. Many subjects in the non-bus group voiced this sentiment by saying that they would like to have some sign or other information to tell them about the lane,

or just simply said, "I really don't know what to do." In summary, the raised devices and the ladder are good candidates for delineation of an HOV lane given accompanying information to this effect.

Study 2

Method. Eight delineation treatments were chosen from the previous experiments based on levels of prohibitive/permissive aspects from the clusters established in Experiment 2 (see Figure 15, Experiment 2). The treatments were evaluated using the pair comparison technique to determine which marking they felt better conveyed a shoulder/breakdown zone idea. Figure 33 presents the eight treatments tested and a sketch of each. Note that the last two incorporate the color treatment on the very prohibitive ladder design. In this case, overlays of the design were placed on a backdrop of an ordinary three-lane highway, each treatment paired against every other, yielding 28 pairs. These were presented as slides for 1 second each, and subjects checked "right" or "left" to indicate their choice for the shoulder zone meaning. The same subjects participated here as in Study 1 just described.

Results and Analysis. Scale values for the shoulder delineation treatments were computed. Figure 34 is a graphic representation of the treatments as they fall along the scale, ranging from perception of the design as "shoulder/breakdown zone" to perception as "free travel zone." The findings indicate that designs with a solid, connected look (6, 11, 14, and 20) are above zero, chosen as the shoulder marking. Dashed designs are perceived as free travel zones, not suited to delineate the breakdown zone (4, 5, and 8). Design 9, the diamonds connected by the single solid line, is a sort of

Marking Code #	Description	Appearance
4	Double Short Dashes	
5	MUTCD Diamond Lane	
6	Solid Lines with Embedded Diamonds	
8	Dash Lines with Embedded Diamonds	
9	Diamonds Connected with Single Line	
11	Ladder	
19	Ladder in Bright Yellow-Green	AS #11 WITH COLOR
20	Ladder in Light Blue	AS #11 WITH COLOR

Figure 33. Delineation treatments tested as connoting shoulder zone.

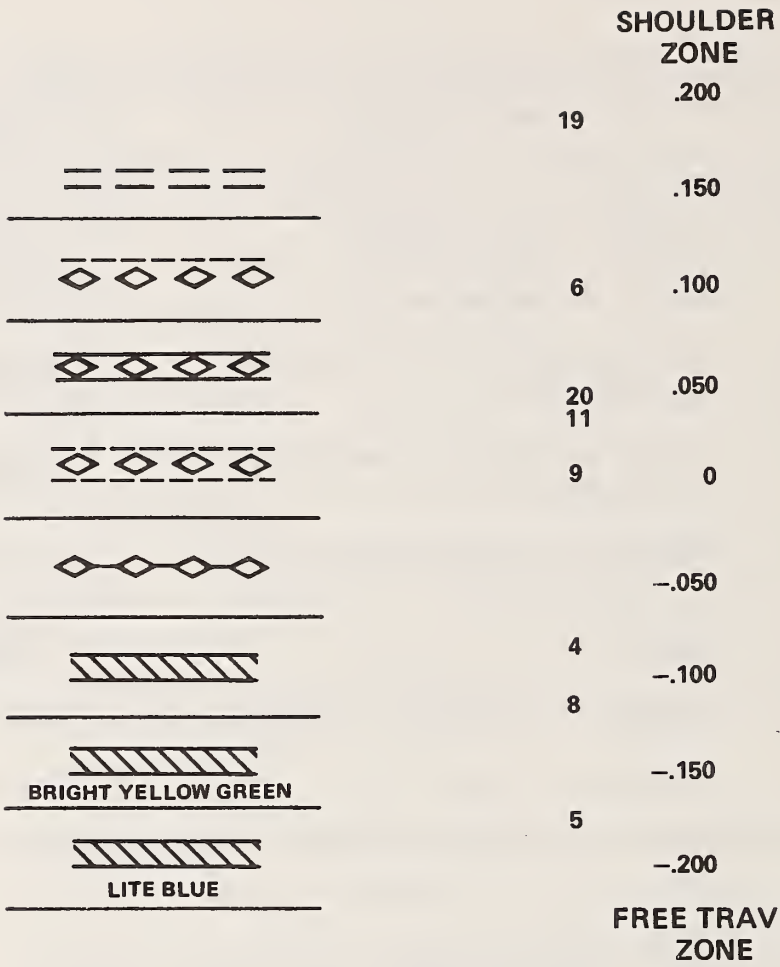


Figure 34. Scale values for perception of delineation treatments as shoulder zone or free travel zone

innocuous entity, falling either way. This is in confirmation of previous data in that it is connected, acting somewhat prohibitive; yet it has a thin look, which is somewhat permissive--or at least amenable to take on some further meaning if additional information was provided.

Study 3

Method. The 12 delineation treatments evaluated in Study 1 (listed and drawn in Figure 30) were used for test here. Signs were designed to accompany each. Four key signs containing priority lane information were created: one with no symbol, one with the diamond symbol only, one with the ladder symbol, and one with both the ladder and the diamond. Two variations on the word only signs were created to counteract learning effects. Ten other signs were created, in the following categories: two construction zone area type; four with parking/no parking connotation; two indicating a lane drop, right turning zone; one overhead lane control for all vehicles, and one pure distraction--"I don't know" element. Therefore, assessing the association for the candidate ladder design and the diamonds in the various combinations was a task embedded among distracting elements: cones, open dashes, and parking stalls. Figure 35 shows small drawings of each sign used with an identifying number and arranged in the categories as just described.

Each of the 12 delineation treatments was overlaid onto the right lane of the urban arterial painting described in Study 1. Two slides were taken of each, producing 24 slides with the bus lane marking to the driver's right. Examples are shown in Figure 36. Twenty-four preparatory slides were also produced showing the drivers proceeding down the street prior to encountering the HOV lane to the right. Figure 29 is a photograph of

Sign #	Category	Appearance
1	Priority Lane Information - Standard MUTCD	
2	Priority Lane Information Words Only	
3	Same as 2	
4	Same as 3	
5	Priority Lane Information Ladder Symbol	
6	Priority Lane Information Ladder & Diamond Symbols	
7	Construction Zone Type	

Figure 35. Signs used in Experiment 4, Study 3.

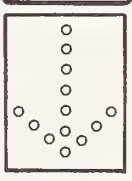
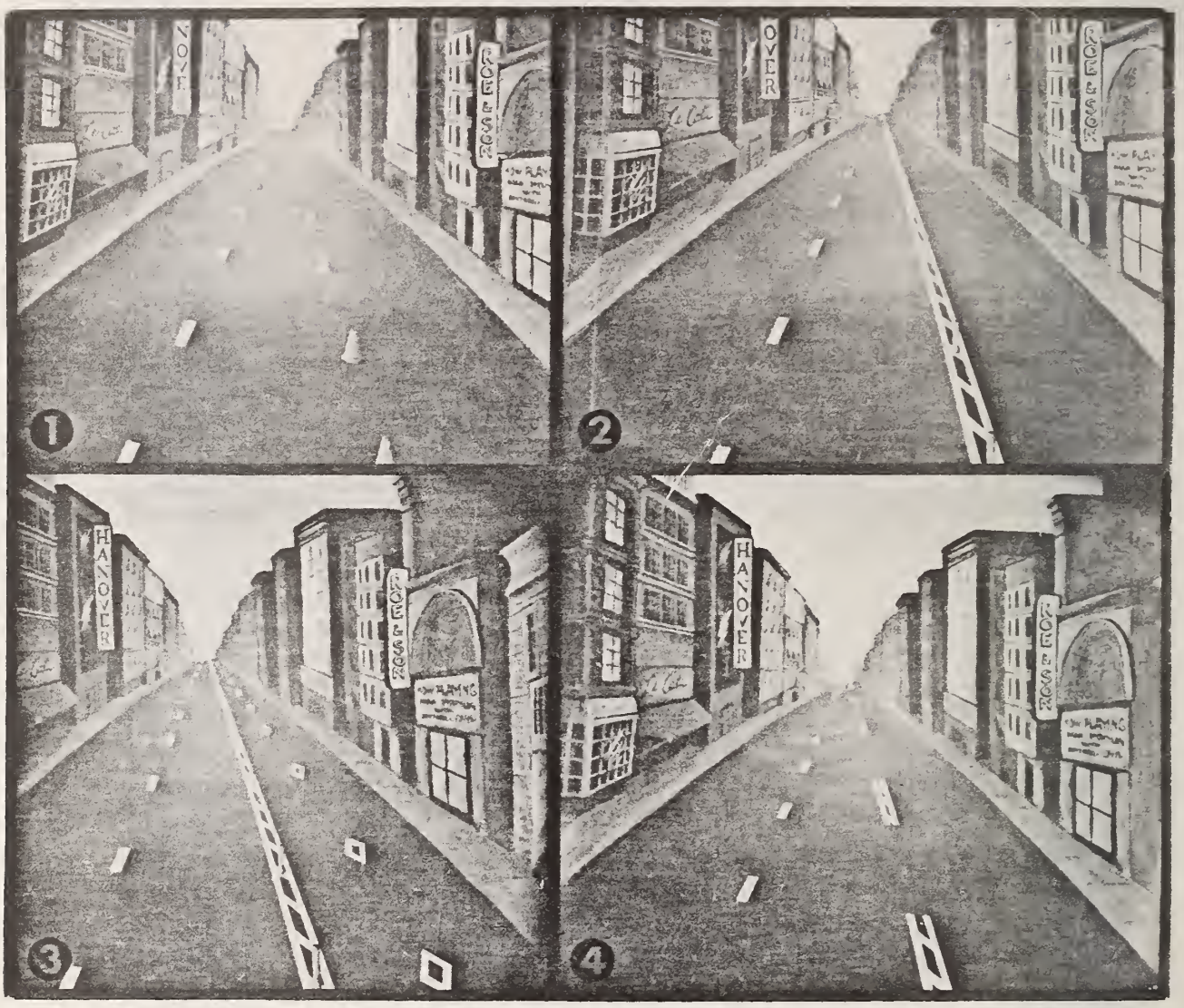
8	Same as 7	
9	Parking/Permissive	
10	Same as 9	
11	Parking/Prohibitive	
12	Same as 11	
13	Lane Drop/ Right Turn Zone	
14	Same as 13	
15	Overhead Lane Control	
16	Distractor element	

Figure 35 (continued).



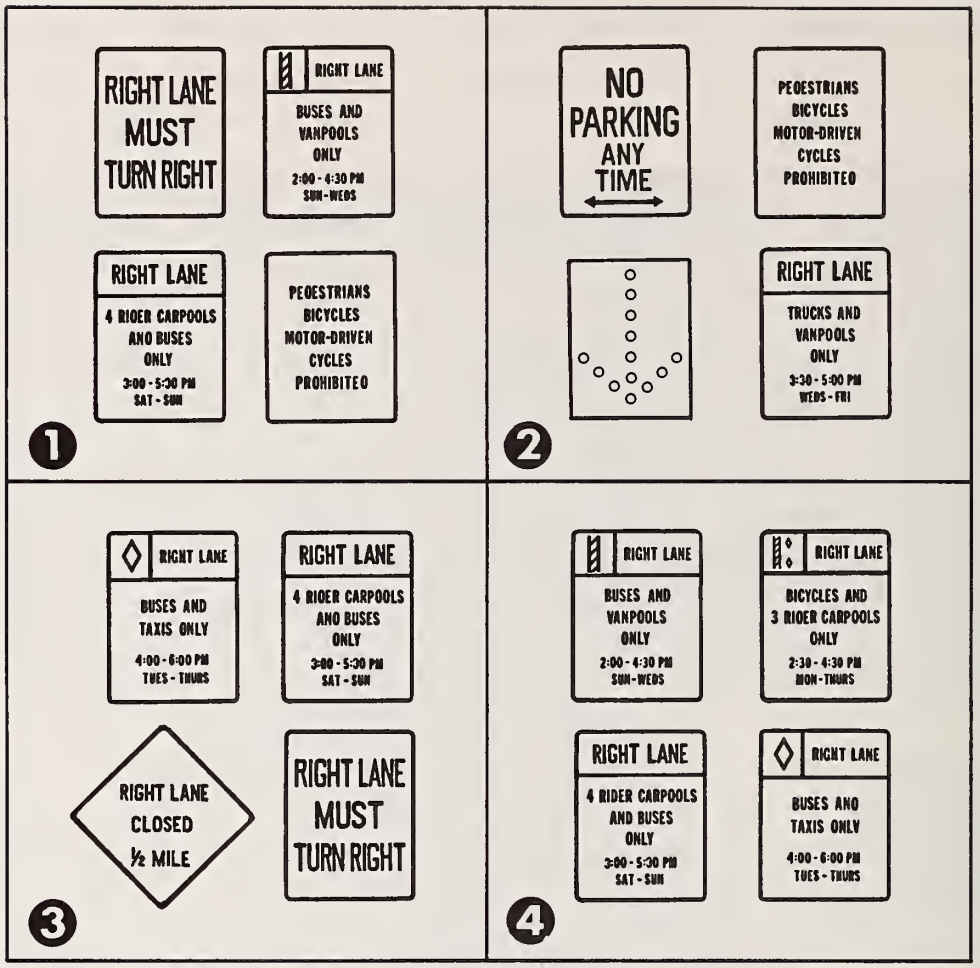
1. Treatment B - Cones only
2. Treatment D - Ladder & Cones
3. Treatment E - Cones/Ladder/Diamonds
4. Treatment I - Ladder-Dash

Figure 36. Examples of marking slides for Experiment 4, Study 3.

this preparatory slide. The stimulus signs to be associated with each treatment were drawn on 8" x 10" sheets, then placed four at a time upon a four-quadrant plain backdrop. Each quadrant was numbered 1, 2, 3, or 4. For each given delineation, the four-sign slide gave the subject four choices from which to choose as being associated with the road marking seen on the previous slide.

Figure 37 shows a few examples of the four-quadrant sign slides produced. The subject viewed a three-slide set for each decision trial: first, driving down the street; second, encountering the new road marking to the right; and third, exposure to four signs, one of which was to be selected as corresponding to the use of the right lane. Thus, a total of 24 trials was given in random order, showing each marking two separate times, followed by the four-sign slide each time. The signs were assigned to quadrants randomly, and with a different assignment for trial one than for trial two. Signs chosen for test with each marking were selected by category, always including one HOV sign, with more than one for the key treatments: the ladder and diamond markings and their combinations. The task was to select the quadrant number and then write information seen as time permitted.

The slides were presented at the following exposures: preparatory slide, two seconds; marking slide, three seconds; four-sign slide, six seconds; and intertrial interval, ten seconds. (The exposures were determined on the basis of pilot testing to establish minimum exposure times for assimilation, but being sure to limit excessive deliberation and to prohibit cognitive memory processes from beginning. The idea was to capture first impressions and associations.) Appendix C contains copies of instructions given and response forms.



1 Four-sign slide for Treatment "D"

2 Four-sign slide for Treatment "K"

3 Four-sign slide for Treatment "A"

4 Four-sign slide for Treatment "E"

Figure 37. Examples of four-sign slides on four-quadrant background.

Twenty-six drivers participated in the study; 10 males and 16 females, aged from 16 to 59. Eighteen were over 30, and eight were under 30. They were drawn from the Baltimore metropolitan area, and over half acknowledged no familiarity with bus/carpool lanes or their operations.

Results. Table 25 summarizes the stimuli presented and the responses given. The first column is the marking that was shown. Column 2 is the identifying number of the signs shown (refer to Figure 36 for drawings of each sign), while the trial columns, 3 and 4, show the proportion selecting each of the given signs as associated with each marking. For example, marking A, post cones alone, was followed by the four-sign slide containing sign numbers 1, 2, 8, and 13. On trial number 1, .81 of the sample selected sign 8 as associated with marking A. On trial 2, .73 selected sign 8. If there were no association between a given marking and any sign, the expected frequencies for the four signs would be .25 each. A z-test was performed to determine which sign selections differed significantly from this chance expectation. Asterisks on Table 25 mark those proportions that produce a z of 2.58 or greater, $\alpha < .01$ that it is a chance selection. The z computation is based on the following formula (Guilford, 1965):

$$z = \frac{p - p}{\frac{P(1-P)}{N}}$$

where

p = obtained proportion
P = expected proportion (.25)
N = number of observers

Given this, any proportion > .469 meets the significance criterion.

Table 25

Markings and Signs Shown to Subjects with Proportions Selecting Each Sign for a Given Marking

MARKING	SIGN #	TRIAL 1	TRIAL 2
A	1	.04	.08
Post	2	.00	.15
Cones	8	.81*	.73*
	13	.15	.04
B	1	.17	.18
Regular	3	.30	.32
Cones	9	.09	.23
	14	.44	.27
C	1	.56*	.54*
Post	2	.07	.00
Cones &	8	.37	.35
	11	.00	.11
D	2	.12	.12
Post	5	.48*	.69*
Cones &	13	.16	.12
Ladder	16	.24	.07
E	1	.27	.36
Post Cones	2	.04	.08
Ladder &	5	.15	.20
	6	.54*	.36
F	5	.92*	.76*
Ladder	7	.04	.08
	12	.04	.12
	16	.00	.04
G	1	.20	.23
Ladder &	5	.24	.12
	6	.40	.50*
	11	.16	.15
H	1	.81*	.72*
MUTCD	4	.08	.08
	12	.08	.08
Lane	16	.03	.12
I	5	.69*	.81*
Ladder-	10	.12	.08
Dash	14	.12	.08
	16	.07	.03
J	1	.12	.04
Ladder-	5	.15	.19
Dash &	6	.50*	.65*
	13	.23	.12
K	4	.27	.35
Reversible	12	.19	.31
Lane	15	.15	.11
Dash	16	.39	.23
L	1	.15	.19
Parking	3	.04	.15
Stalls &	9	.69*	.62*
	11	.12	.04

Analysis. The findings confirm the expected associations. Treatments with just the diamond (C and H) are associated with sign 1, the standard MUTCD sign. Treatments with just the ladder configuration (D, F, and I) are associated with sign 5, the HOV sign with the ladder symbol. Ladder/diamond combination markings (E, G, and J) were most frequently associated with sign 6, containing the combination ladder/diamond symbol. The exception is treatment L, the parking stalls with embedded diamonds. Most readily associated with this is sign 9, a parking zone sign. The strength of the diamond lane here is subordinate to the parking lane. This confirms previous data.

Treatments with just the cones are associated with a construction zone concept, i.e., marking A with sign 8, a very strong association here. Marking B deliberately did not have the construction category option, and thus was found to be a source of confusion. Obviously, more information is needed by drivers to draw the cones away from the construction meaning to the priority area meaning. This very need is met when cones are coupled with the ladder (D), diamonds (C), or both (E). Here a symbol and transference effect occurs, and the cones fit as delineators.

The strongest marking/signing associations are made without cones, the ladder alone (F), the diamond lane (H), and the ladder dash (I), as evidenced by the very high proportions choosing the corresponding symbolic signs. The transference was effective and seems amenable to field test; however, the concept is based on being able to assimilate the rules information in the time allowed. Over half of the respondents had difficulty reporting information on the signs, although what was reported was accurate.

The final distractor element, reversible lane dashes (K), created the expected confusion. Subjects did not even recognize its true meaning and coupled it with the overhead lane control.

Study 4

Method. The objective of this final study was to relate sign placement to physical lane markings. A pictorial representation of an urban curb bus lane with standard MUTCD markings was prepared. This was accomplished by photographing the arterial painting used previously, overlaid with the HOV lane beginning midway down the street. This photo was then placed on a sheet of paper, copied, and used as the stimulus. Figure 38 shows the stimulus photo and instructions used to guide subjects in the placement task. Subjects were simply directed to make a small "X" along the sidewalk to indicate where signs should appear. The same subjects participated in this study as in Study 3 preceding.

Results. Data were scored by dividing the photograph into six zones, three preceding the beginning (entrance) to the HOV lane, and three along it into the horizon. Figure 39 shows these scoring zones. For each subject, the number of signs placed in each zone was recorded in a tabular fashion, and this is presented in Table 26.

Analysis. Several important trends are obvious by inspection of the data. First, 92% would place a sign in Zone 1, well in advance of the entrance to the HOV lane. This underscores the need for advance signing. The need tapers off until the entrance (Zone 4), where 70% would place signs. The high number placing signs out onto the horizon (Zone 6) shows that subjects are really asking for periodic continuation of signing for as long as the lane proceeds. Some subjects penciled this through on the answer form.

Below is a drawing of a city street where a bus lane begins in the right curb lane, about midway down the street. As you can see, the different striping marks the beginning of the bus lane. Signs must be placed along the side to tell drivers what the new lane is for and who can use it. Your job is to place "X" marks on the sidewalk to show where these signs should be placed. In doing this, think of these things:

- Where should the first sign be?
- How many signs should there be altogether?

Figure 38. Stimulus photo for Experiment 4, Study 4.

Figure 39. Scoring zones for sign placement.

Table 26

Sign Placements Along HOV Lane
Photo Representation

	Before HOV Lane			Along HOV Lane			
Subject #	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Total
1	1	1	-	-	-	-	2
2	1	1	-	-	1	1	4
3	-	-	-	1	-	2	3
4	1	-	-	-	-	-	1
5	1	-	1	2	-	2	6
6	1	-	-	1	-	1	3
7	-	1	1	1	-	2	5
8	-	-	-	1	-	2	3
9	1	-	-	1	1	1	4
10	1	-	-	1	-	1	3
11	1	-	1	-	-	-	2
12	1	1	1	-	-	-	3
13	1	-	1	-	-	-	2
14	1	1	-	-	-	-	2
15	1	-	1	-	-	-	2
16	1	-	-	-	-	1	2
17	1	-	-	-	-	3	4
18	1	-	-	1	1	1	4
19	1	-	-	-	-	-	1
20	4	2	1	3	1	-	11
21	-	-	-	1	1	2	4
22	-	-	-	1	2	2	5
23	1	1	-	1	1	-	4
24	1	-	1	-	1	1	4
25	1	2	-	2	-	1	6
26	1	-	-	1	--	1	3
Totals	24	10	8	18	9	24	

Before HOV Total = 42

Along HOV Total = 51

Another finding is that nearly three-fourths (73%) marked in three or more signs along the corridor, instead of one or two. This again shows the desire for information about the lane and repetition of it.

It is clear that advance placement of the first sign containing the rules of use information about the lane is vital. Also, consistent repetition of the signing at frequent intervals is indicated. One subject actually asked that the first sign be placed 1/4 mile in advance of the HOV lane beginning. Another subject tapped a question of great interest by suggesting that the number of signs be "one less than the number of pavement diamonds." Although these comments are few and the total subject sample small, they do point up the creativity possible given a larger subject sample, and how this might provide real insight into problems and needs for this most crucial element in the roadway system: the driver.

Conclusions

These four short studies have concluded the laboratory effort of Task 3 by attacking parameters related to HOV lane delineation that serve as a prelude and input to actual field testing. Below is an outline summary of each study and inputs to field design.

Study 1. Use of cones, skip-ladder design, and parking stalls along HOV lanes.

- Given an HOV lane scenario, orange cone and ladder treatments effectively delineate the lane.
- Combination treatments using the ladder in a skip fashion are not seen as HOV lanes.

- Parking stalls along the diamond lane overwhelm the HOV concept and lose it.
- Cones and the ladder combinations without the scenario of the HOV lane create confusion as to meaning for entry or non-entry.

Study 2. Perception of highway shoulder/breakdown zone.

- Designs with a solid, connected look are seen as a shoulder zone, regardless of design element (i.e., ladder striping or diamond configuration).
- Dashed designs are perceived as free travel zones, not shoulders.
- Thin diamonds connected by a single line are a kind of neutral striping, not decipherable as having a particular meaning for entry or non-entry. Another study is needed.

Study 3. Delineation symbol with sign association.

- A pavement delineation symbol is clearly associated with a sign containing the same symbol. The diamond and ladder-dash symbols were the most effective of the symbols tested.
- Diamond symbols are not effective when superimposed on parking stalls.
- Orange channelizing devices such as cones connote a construction zone to drivers. If used in an SUL context, they should be associated with a diamond symbol.

Study 4. Placement and number of signs along HOV lanes.

- Use of advance signing for HOV lane employed by 92% of sample.
- Use of entrance signing (signs placed at HOV lane commencement) employed by 70% of sample.

- Subjects place three or more signs along the lane rather than one or two, indicating need for repeated information.
- Many subjects place signs far into distant horizon (92%), indicating need for signing periodically for duration of lane.

These various studies have specific input to the use of the ladder, the use of cones, and the possible influence of a solid design as meaning a shoulder: namely, that these delineation treatments, as single elements or combinations, must be employed in the priority lane setting accompanied by other informational sources, most likely signing. It was demonstrated that associations are made between the delineation design and its symbolic counterpart on a sign. The final study (Study 4) most pointedly served to emphasize the need for repetitious, periodic display of the reserved lane information on signs.

The survey questions from both testing sessions revealed participants strongly in favor of the reserved lane concept for buses and other high-occupancy vehicles (90%). Many felt that this was good for the ecology and energy situation and in keeping with the times. Those opposed seemed to be so because the lanes seemed to be operating inefficiently and tying up traffic in the general lanes due to buses crossing in and out. Over half of the sample questioned (60%), however, indicated that they mostly drove alone and were not frequent users of high-occupancy vehicles. Obviously, the bus lane concept finds great acceptance on paper. Its actual impact in the real world is a question to be probed when encountering drivers in the roadway setting.

Synthesis

The preceding descriptions have detailed a series of experiments investigating delineation design parameters. Following are the major findings from each.

1. Inherent meanings of delineation treatments in terms of driver tendency to cross or not to cross (prohibitive-permissive displays).
   - Dash or skip designs are more permissive, regardless of symbology or color.
   - Solid symbols, i.e., diamonds, are more prohibitive than diamond outlines.
   - Line stroke width has little effect on prohibitive-permissive meaning.
   - Color may add a prohibitive dimension in some cases but is not a primary factor.

2. Effects of spacing and density of design elements in delineation lines.
   - There are no appreciable prohibitory effects of 1-foot, 2-foot, or 3-foot line widths.
   - Skip-dash treatments are permissive, regardless of width.
   - Diamonds connected by a single line or between two solid lines are associated by some drivers with an SUL.
   - The crosshatch ladder design is the most prohibitive treatment in the laboratory and in a controlled field setting.
   - The greater the density of design elements per gap width, the more prohibitive the line.

3. Observation studies of field operations--concurrent flow bus lanes--to possibly deploy delineation schemes near right-turn areas.

- High bus and queue volumes prohibited deployment plans.
- Contacts with local officials and location of vantage points were made.
- Sense of "driver sentiments" toward SULs was obtained. Many brief conversations with drivers and pedestrians seemed favorable about the concept, with strong reservations about its actual operational success.

4. The use of cones, ladder-dash designs, and parking stalls as impacting on identification of bus lanes.
   - Given an SUL scenario, cones are an effective delineator of the lane; otherwise, they are associated with construction work.
   - Combinations of ladder-dash designs and cones create confusion.
   - Parking stalls overwhelm the SUL concept and bury it.

5. Perception of certain SUL delineation treatments as meaning a shoulder/breakdown area.
   - Designs with a solid, connected look are seen as shoulder zones, regardless of symbology.
   - Dashed designs are seen as free travel zones, not shoulders.
   - Thin diamonds connected by a single line are seen as neutral, not decipherable as promoting or prohibiting entry.

6. Association of SUL lane delineation with candidate symbolic signing.

   - Marking treatments are associated with signs containing their symbolic counterparts.
   - Cones alone are not associated with the SUL concept, but become so when combined with diamonds and/or ladders.
   - Ladder-dash treatment and parking stalls alone do not associate to SULs. Addition of pavement diamonds is helpful to ladder-dash designs but not parking stalls.

7. Placement and number of signs along an SUL.

   - Subjects advocate use of advance signing to mark an SUL (>92%).
   - Subjects overwhelmingly place a sign at the entrance to an SUL (>70%).
   - Most often, more than three signs are placed along the SUL rather than just one or two. The need for repeated information was seen here.

Each study has produced valuable answers to questions raised from the driver information needs analysis of Task 2. In addition to each set of findings for each study, questionnaire data collected from each group provided a common thread of information linking the various findings and procedures. Many studies used identical rating and ranking measures validating a quantitative identification score with preference measures. For example, Experiments 1 and 2 validated Guilford's scaling technique with preference measures of design meanings.

Finally, subject samples were drawn from a wide area including Columbia-Baltimore, Maryland; and Central Pennsylvania, and providing a wide age range and stratified random selection. Given such diverse samples and such clean, reliable data, these results are felt to be highly generalizable as inputs to final signing and delineation system designs.

CHAPTER 7
CONCLUDING REMARKS

This volume first described the literature search, SUL inventory, site visits, and information analysis of SULs. Based on this input, initial SUL information systems were then designed, and, finally, the questions and issues raised by these tasks were addressed in a series of signing and delineation laboratory and closed field experiments.

The use of products from the analytic and experimental tasks to mold the operational (field) evaluations is described in Volume III of this report. Also, the description of the field experiment findings and suggested SUL information systems are documented in Volume III.

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APPENDIX A

INITIAL SUL INFORMATION SYSTEM DESIGNS

Freeway Signing and Delineation Systems

Cell #1:* Freeway/Reserved/Non-Reversible/ No Physical Separation

This cell includes concurrent flow reserved lanes such as are found on I-95 in Miami, the San Bernardino Expressway in Los Angeles, or the Banfield Expressway in Portland. Figure A-1 shows the information needs for this cell and illustrates a possible fixed signing system for meeting the information requirements.

A major problem with many Cell #1 type facilities is the part-day restrictions. A lane may be reserved only in the a.m. (or p.m.) peak, but open to all traffic the remainder of the day. The signing must convey the different types of operations during the day. Fixed signing accomplishes this, indicating hours of restriction. One variation of System A would have a fixed sign or panel stating, "Lane Open To All Traffic At Other Times." System B is variable message signing, which simply indicates the lane is open to all traffic during non-restricted hours. During restrictions, the complete information set would be provided.

Cell #2: Freeway/Reserved/Reversible/ Physically Separated

The most complex situation represented by this cell is the reversible high occupancy vehicle (HOV) lanes typified by the Shirley Highway (I-395) facility in the Washington, D.C. metropolitan area. A less complicated example (from an information requirements standpoint) from this cell is the reversible but not restricted express lanes on the Kennedy Expressway in Chicago, Illinois.

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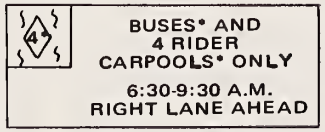
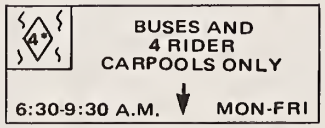
*Cell numbers refer to Figure 2, page 40.

	Information Requirements	Signing System A**	Signing System B
	• Existence		Same message but can be changed/blanked out during non ◊ hours
Approach	• Type of Restriction • Egress Limitation • Type of Operation • Location		Same message but can be changed in non ◊ hours
			Same message but can be changed in non ◊ hours
Entrance	• Existence • Location • Type of Restriction • Egress Limitations		Changeable message– This lane open to all traffic
Through	• Repeat Entrance Information and provide standard exit signing • Continuous Lane Definition		
Exit	• End of Restricted Lane • Standard Exit or Merge Signing	See MUTCD	Blank out Sign See MUTCD

* Indicates word,component,etc., tentative and subject to further study before design decisions made.
** These graphic representations are not design drawings, i.e. font, letter size, height to stroke width/ratio are not indicated.

Figure A-1. Possible signing systems for Cell #1.

One important difference between these two types of facilities is the desirability of attracting drivers to the facility. In the restricted SUL, the target audience is local commuters in HOV modes. Such people know their destinations and know, through local publicity, the route (entrances and exits) of the SUL. Generally there are few unfamiliar drivers in the peak hour traffic streams, especially who qualify for a restricted SUL, and the goal of signing is to keep them from accidentally or naively wandering into the SUL. One means of achieving this goal is to tell drivers who are eligible for the restricted lane, but not provide destination or exit information. The intent here is to withhold information and thereby discourage the unfamiliar non-user from being enticed into the SUL. Figure A-2 shows possible signing for this case.

In some cases, entrance to a SUL will be via ramp, or there might be a restricted ramp going onto an unrestricted freeway. In either case, modified (replace lane with ramp) signs from Cell #2 would fill the information needs.

For those Cell #2 facilities where no HOV restriction exists and all car drivers, particularly through travelers, are encouraged to use the SUL, designation signing is important. Where the SUL does not allow egress at some exits, the next exit should be indicated. When all exits are accessible to the SUL, no unusual destination information is required. Figure A-3 provides a possible signing system for the limited access SUL. Even simpler express lane situations where there is no reversibility, e.g., Dan Ryan Expressway - Chicago and New Jersey Turnpike, can be signed using MUTCD specified guide signing. The information requirements of location, egress limitations, and vehicle limitations can be met without special SUL signing or delineation.

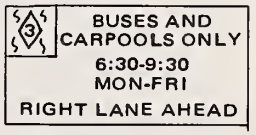
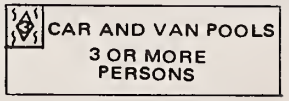
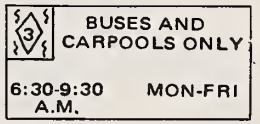
	Information Requirements	Signing System A	Signing System B
Approach	• Existence		Same
Approach	• Type of Restriction • Type of Operation • Location		
Entrance	• Egress Limitation	Purposely not provided	
Entrance	• Type of Restriction		
Entrance	• Vehicle Restriction • Time of Operation • Location		Same but changeable message saying Restricted Lane Closed
Through	• Entrance/Exit Signing	Standard MUTCD signing and delineation	Same
Through	• Trailblaze Entrance Information (as necessary)	Repeat entrance signing as required	Same
Exit	• End of facility		Same
Exit	• Merge or drop lane	Standard MUTCD signing and delineation	Same

Figure A-2. Possible signing systems for Cell #2.

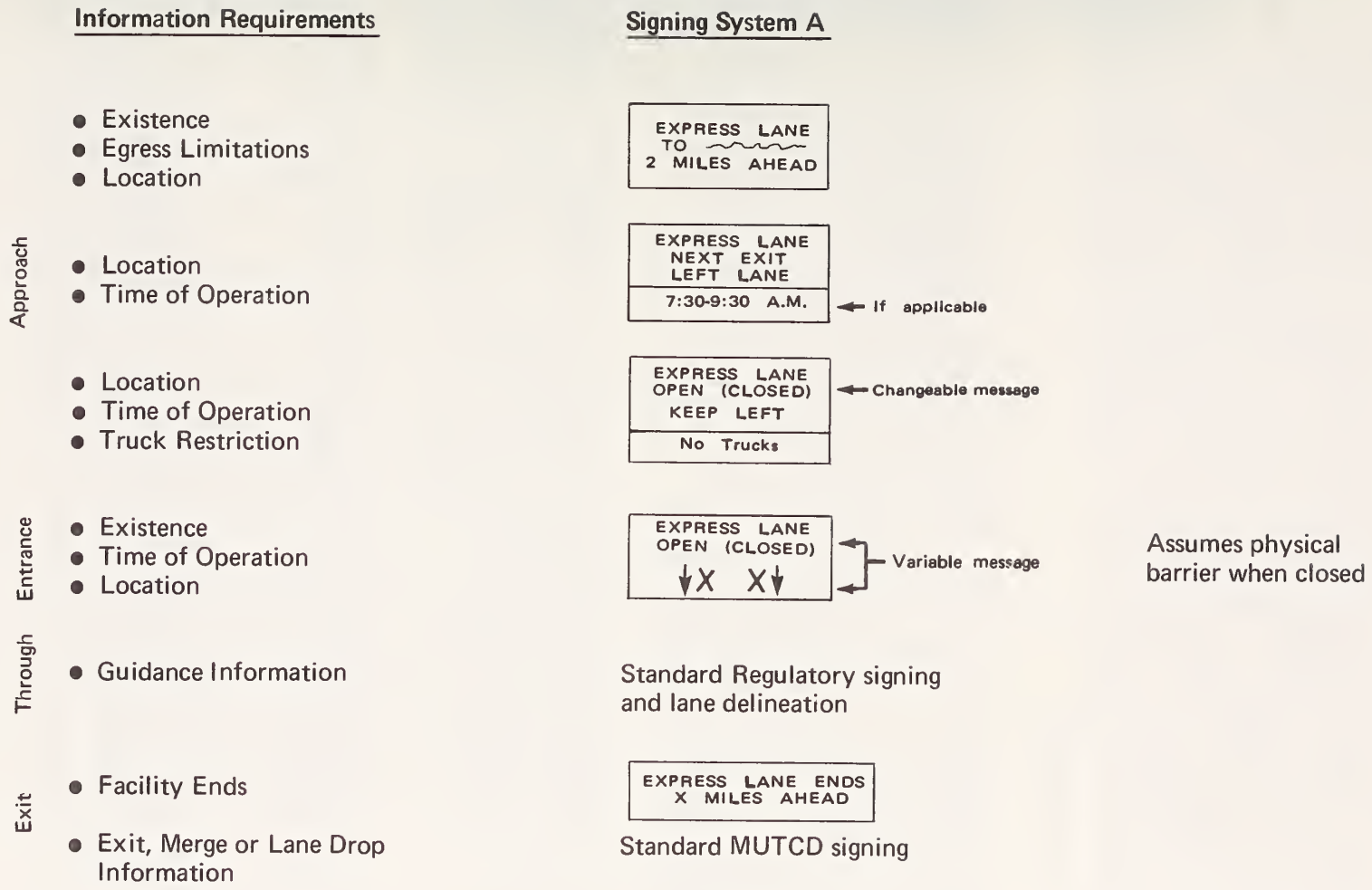


Figure A-3. Possible signing systems for Cell #2.

Cell #3: Freeway/Reserved/Contra-Flow/
No Physical Separation

There are currently only three freeway contra-flow lanes operating; U.S. 101 from San Francisco, New Jersey I-495 to the Lincoln Tunnel, and New York I-495 (Long Island Expressway) from the Midtown Tunnel. Each of these is different, both geometrically and in the signing systems used. However, they do have common information requirements, and the proposed signing system is flexible enough to meet the wide variety of conditions existent and planned.

Several assumptions that impact on the signing and delineation systems should be noted. First, only buses currently use contra-flow lanes. While there has been discussion of allowing wider user population, the assumption was made that only registered or permitted van pools might become qualified users in the future. Drivers of such vehicles can be given specific instructions on the use of the contra-flow lane at the time of registration and at renewal times.

Second, because contra-flow lanes are intended for designated drivers only and the hazard associated with errant drivers unwittingly entering a contra-flow lane analytically appears high, this type of SUL should be relatively obscure. On-site observations at one site found two drivers going into and continuing through, one driver entering and backing out, and several drivers swerving to avoid entering the contra-flow lane; this within a 30-minute filming session.

Third, there has been consideration given to not using post cones to continuously separate the contra-flow from opposing traffic. Regardless of how powerful the signing used, there is a need for continuous delineation of the opposing traffic lanes.

This delineation must be obvious and present when contra-flow is operating, and should not be present during concurrent flow operation. This is important in maintaining the credibility of the delineation treatment. If the treatment is always present but is applicable only part time, it will tend to be ignored. Therefore, some form of changeable delineation system is required. While placement and removal of post cones is expensive, other alternatives, e.g., barricades rising out of the pavement, are far more expensive.

Finally, the use of barrier lane or no barrier lane depends on the possibility of drivers straying into the opposing traffic lane. Roadway geometrics apparently affect such probabilities. Where extensive curvature is encountered for a contra-flow lane, a barrier lane appears advisable. Steep up- or downgrades subject to considerable icing or snow might also be candidates for barrier lane operation. Very long stretches of contra-flow where a break-down, emergency, or stopping lane is deemed necessary may require use of a barrier lane when shoulder space is unavailable. Relatively straight sections of contra-flow can be operated without a barrier lane with no apparent impact on safety. In general, the accident record of freeway contra-flow lanes is better than most other HOV facility operations (Miller et al., 1979).

Given the above assumptions and considerations, a possible signing system is shown in Figure A-4. The information requirements for drivers traveling "against" the contra-flow lane direction can be readily met with MUTCD specified signing. No new or SUL-specific signs appear necessary. Basically, standard lane closure, repeated "two-way traffic" signs, and lane add techniques can be used.

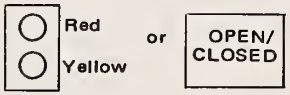
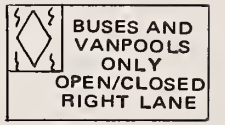
Information Requirements		Signing System A (Buses Only)	Signing System B (Buses and Vanpools)
Approach	• Existence • Vehicle Restriction • Rules of Use • Location	For buses only this information is provided through driver training	
	• Time of Operation	 Changeable Message	
Entrance	• Vehicle Restrictions • Time of Operation • Location	Blank out or changeable message	
	• Rules of Use	Given to bus drivers plus standard regulatory signs covering speed, lights on, etc.	Same
Through	• Location • Rules of Use	Post cones and standard regulatory signs	Same
Exit	• End of SUL		Same
	• Exit Procedure	MUTCD merge, yield signing	Same

Figure A-4. Possible signing systems for Cell #3.

Delineation at the gore or entrance of the contra-flow lane is not depicted. Clearly delineation, be it through paint, movable cones/Type II barricades, or other movable barriers, must not lure drivers into the SUL. Geometric design is also an important factor in a relatively obscure entrance. Normal traffic should clearly flow past the entrance, not have to avoid the entrance. Delineation should positively guide the driver by the contra-flow lane entrance. (However, some delineation must be given to the contra-flow users to show them where to enter the lane.)

Cell #4: Freeway/Reserved/Shoulder/
No Physical Separation

The restricted shoulder SUL only exists at two freeway sites; however, the constraints currently placed on new freeway construction suggest that using shoulders to increase capacity may be a necessity in the near future. For this reason, a signing system is being presented here.

The problem of providing differing information at different times of the day is again apparent for this type of facility. A problem unique to the reserved shoulder situation is cross-traffic entering and exiting the freeway. Where a shoulder next to the median is used, the problem is minimal, but is replaced with difficulty in providing emergency/enforcement pull-off space. Another type of information that must be clearly provided is the "do not stop or park on the shoulder" when operating as a SUL.

The information system shown in Figures A-5 and A-6 is adapted from the Cell #1 signing. Whenever possible, similar signing is being developed so that standardization will be

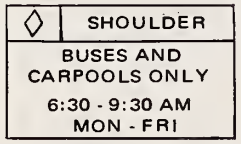
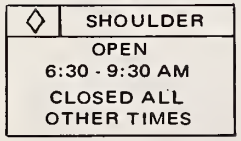
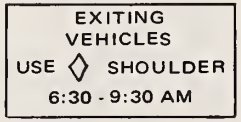
	Information Requirement	Signing System A	Signing System B
Approach	• Existence	1.	Same but message can be blanked out or changed
Approach	• Location • Type of Restriction • Time of Operation	2. 	Variable message sign also saying "Use Shoulder for Emergency Stopping"
Entrance	• Location • Type of Restriction • Time of Operation	Same as approach 3. 	Same as approach
Through	• Location • Type of restriction • Time of operation	Same as approach	Same as approach
Through	• Use SUL for exit lane	4. 	Blank out sign
Through	• Repeat entrance information at entrance ramps	Use signs 1 and 2 on ramp	Blank out signs
	(See Figure 8 for sign placement diagram)		
Exit	• End of facility		Blank out sign
Exit	• How to exit	Standard MUTCD merge or lane drop signing	Blank out signs

Figure A-5. Possible signing systems for Cell #4.

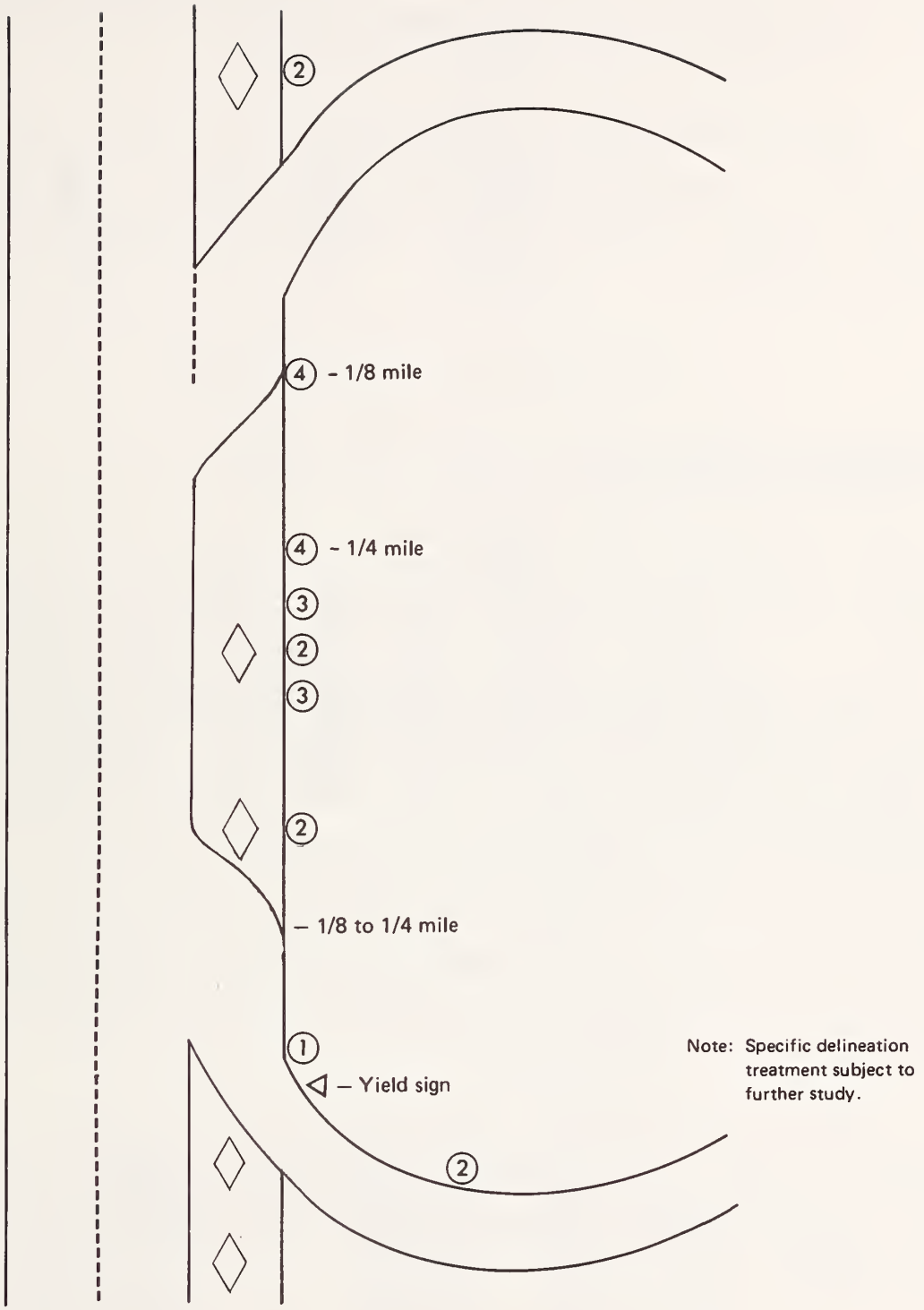


Figure A-6. SUL sign placement at exit and entrance ramps – Cell #4 facilities.

possible. This should contribute to creating an expectancy in drivers that will be valid across restricted SULs, as well as to ease of understanding and implementation.

There is one SUL facility operating as a non-reserved shoulder for through traffic during peak hours. This is a simple version of Cell #4, so a separate signing system need not be created.

Arterial Special Usage Lanes

Cell #11: Arterial/Reserved/Non-Reversible/ No Physical Separation

This cell represents the most frequently encountered type of SUL: the HOV bus/carpool lane usually operating during peak hours, but on occasion being reserved 24 hours per day.

The major difficulties encountered in this type of facility are conveying all the required information on the relatively constrained arterial street sizes, defining when a right turning vehicle can enter the diamond lane to make the turn, and general observance (or conversely, enforcement) of the lane restrictions. The arterial setting poses the problem of overhead versus post-mounted signs. The esthetic and clutter considerations of overhead signs must be compared to any gain in driver understanding and/or compliance.

Given these problems, the signing systems illustrated in Figure A-7 must be considered very general representations of the information that must be conveyed, not necessarily the final sign design.

The delineation treatment for a restricted bus lane presents two problems. First, such SULs are often used only during peak

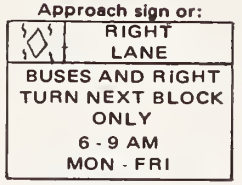
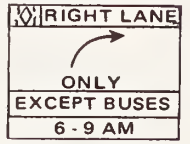
Information Requirements	Signing System A	Signing System B
Approach • Existence • Location		Blank out sign
Approach • Location • Vehicle restriction • Time of operation • Rules of use	 MUTCD - "No Parking 7-9 AM" signs	Blank out sign
Entrance • Vehicle restriction • Time of operation • Location • Rules of use	Approach sign or:   At every intersection where right turn is permitted	Blank out signs Different methods of indicating right turn, e.g., arrow with slash, car and arrow.
Through Same as entrance	Same as entrance	
Exit • End of facility • How to exit	 MUTCD merge or lane drop signing	

Figure A-7. Possible signing systems for Cell #11.

hours, so unusual delineation would have to be ignored most of the day. Second, these lanes, when not restricted, are often used for parking. Incorporating any type of diamond in mid-lane, along with parking stalls, creates visual clutter and confusion.

Possible alternatives include a standard dashed strip with a diamond interspersed between dashes, standard dashes with diamonds off-set into the SUL by a few inches, parking stalls with small diamonds in the parking stall, or a much wider dashed stripe, i.e., 8-inch or 10-inch but no diamonds. The optimum solution would be some form of changeable delineation; however, the cost of setting cones or having some coverable or raisable delineation makes such options infeasible at this time.

Where a SUL runs 24 hours a day, the above treatments are more likely to be effective. Additionally, some form of narrow mountable curb, rumble strip, or other raised delineation would likely have a beneficial effect on compliance.

Cell #12: Arterial/Reserved/Reversible/
No Physical Separation

The only site with this type of operation is the Kalanianaole Highway in Honolulu. Part of the facility is reversible and reserved, but the majority of the roadway is a non-reversing reserved bus/carpool lane. The latter part of the SUL falls within Cell #11, but the former part is unique. Because it is a one-of-a-kind facility, no special signing/delineation system was developed. Should such a system be required, a combination of Cells #11 and #17 (reversible lanes) signing would meet the information requirements.

Cell #13: Arterial/Reserved/
Contra-Flow

Arterial contra-flow bus lane SULs all currently operate in one lane and in a direction to make the street operate like a two-way street, albeit with a disproportionate number of lanes in each direction. Typically these streets are signed as one-way facilities and this is, in fact, not totally true: buses are coming from an opposing direction. This is a problem for traffic (vehicular and pedestrian) crossing the SUL.

All currently operating facilities in this cell have some form of physical delineation. The devices used include raised mountable curbs, permanently mounted cones, widely spaced posts with signs, and portable cones. Permanent barriers are possible since all current facilities operate 24 hours.

Signing is intended to keep non-users out of the lane. Bus drivers receive special instruction and training to know where the SUL is and who can use it. The major purpose of signing is to keep the non-user out of the contra-flow lane at entrances and exits and all along the facility. Figure A-8 illustrates a signing option for arterial contra-flow facilities.

The recommended delineation is a double yellow stripe separating contra-flow and opposing traffic lanes. In addition, day-glo or flourescent yellow post cones should be permanently installed along the SUL. Wherever a street or alley crosses the SUL, a Keep Right sign with arrow (see Figure A-8) should be mounted on the post. To remind pedestrians of the two-way traffic, yellow arrows with the word "Buses" could be painted on the pavement at intervals along the SUL. This would supplement signs (see Figure A-8). Some form of auditory delineation could also supplement signing. Bus drivers could be encouraged to use

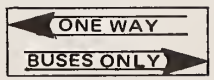
	Information Requirements	Signing System
Approach	• Existence	
Entrance	• Vehicle Restriction	
	• Location	Indicated by overhead and/or double side mounted signs.
	• Rules of use	Standard regulatory signing along SUL and bus driver training
Through	With flow of SUL – • Clear definition of SUL	Provided by solid double yellow line and post cones.
	• Warning about cross-traffic/pedestrians	Driver training and standard MUTCD
	Against flow of SUL – • Location	Provided by solid double yellow line and post cones
	• Existence of traffic in opposite direction	ALSO PRESENCE OF BUSES IS A POSITIVE INFORMATION SOURCE
	Across flow of SUL – • Existence of traffic in two directions	
	• Turn Restrictions	Standard MUTCD verbal or symbolic MUTCD signing
	Pedestrians • Existence of two-way traffic	Same as above plus
Exit	• End of facility	Depends on geometrics of SUL – standard MUTCD signing, e.g., RESUME TWO-WAY TRAFFIC or ONE-WAY ROAD may suffice.

Figure A-8. Possible signing system for Cell #13.

their horns, buses could be equipped with unique sounding horns, or buses could have bell/beeper devices that would sound every X feet (similar to the bell on a railroad locomotive).

Cell #14: Arterial/Shoulder/Reserved/ Non-Reversible/No Physical Separation

There is only one arterial shoulder SUL facility in existence; however, the discussion and rationale for creating freeway shoulder SUL signing applies equally to the arterial situation.

The information requirements for this facility are the same as those found in Cell #11. The only addition is the no parking or stopping requirement during operating hours. A combination of the Cell #11 and Cell #4 signing meets these information requirements, and no new signing need be generated.

There is a particular danger for cross traffic, however. If there is not very clear sight distance in both directions from a stop line before the shoulder begins, entering drivers will tend to stop with part (or all) of their vehicle on the shoulder. The hazard to HOVs is obvious. This same situation applies to cross streets, driveways, and parking lot entrances. If clear sight distance is not possible, some type of sign warning that through buses use the shoulder is necessary, e.g., WATCH FOR BUSES ON SHOULDER, 7-9 AM, MON. - FRI.

Cell #15: Arterial Transit Lanes/Malls

While these facilities qualify as SULs, the information requirements are quite simple, e.g., the SUL is not open to regular traffic. Since all except bus (and perhaps emergency) vehicles are to avoid this type of SUL, the most effective way to solve the information requirement is not with signing. If

roadway geometrics are designed so the main route looks to the driver like it goes around or at least not into the transit mall, the majority of drivers will follow the major roadway. Some signing will be necessary at entrances to transit lanes so that unfamiliar drivers and others will be adequately notified that they may not enter. Modified MUTCD signs serve this purpose, e.g., DO NOT ENTER EXCEPT BUSES or NO RIGHT TURN EXCEPT BUSES. Standard traffic control devices and regulatory signs adequately control entering, through, and exiting SUL traffic. No special delineation is required.

Cell #17: Arterial/Reversible/ Non-Reserved/No Physical Separation

Reversible lanes are becoming more common as the demand to improve roadway capacity without new construction increases. The real-time lane control signal system found in the MUTCD has an empirical base (Forbes, Gervais, & Allen, 1960), but is not universally applied. For long reversible facilities, lane control signals become expensive to install and maintain. When these SULs go through residential or parkland areas, aesthetic objections may arise. In addition, there is an operational problem when lane control and traffic signals are interspersed along a roadway. At two sites the traffic engineers commented that drivers attended the lane control signal and did not notice or ignored the traffic light. Thus a green arrow occasionally "drew" a driver through a red stop light. Several solutions are possible for this problem. By increasing spacing between a stop light and lane control signal, the likelihood of missing the traffic signal should be reduced. If the lane signal needs to be fairly close to the traffic light, i.e., at the start of the SUL, the first set of green arrows could be operated at lower intensity, thus lowering brightness contrast and conspicuity. Also, a polarized lens or shade could be used to block the green arrow

from view until the driver is past the signal. In combination with these solutions, the traffic light lenses could be enlarged, light fixture placement changed slightly, lamp intensity (brightness) increased, additional signal heads installed, and WATCH FOR SIGNALS AHEAD signs installed before the intersection.

Because the overhead real-time lane controls cannot always be used, a side-mounted (post) signing system is included as an alternative.

Certain of the information requirements for this SUL were not met in existing signing systems, so several new signs were developed. Figure A-9 illustrates possible signing systems. Rarely was approach signing used before a reversible lane; the first hint of a SUL was right at the entrance. The other area requiring new signing is lane availability for drivers turning onto the SUL. Drivers turning left onto a reversible lane, particularly where lane control signals are not used, may not know what lane to enter. The resulting hazard is opposing cars in the same lane with head-on or side-swipe accident potential.*

The delineation specified for reversible lanes in the MUTCD has been relatively well accepted and is used where reversible lane signing is lacking. However, a study by Gordon (1976) indicates that yellow should be associated with a hazard. Contra-flow traffic should not be marked with yellow. Also, the double dash is not understood by many people. Analytically, another problem with the double yellow dash scheme is that it does not clearly define which lanes are reversing.

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*During one of BioTechnology's site visits, a minor accident of this type was observed.

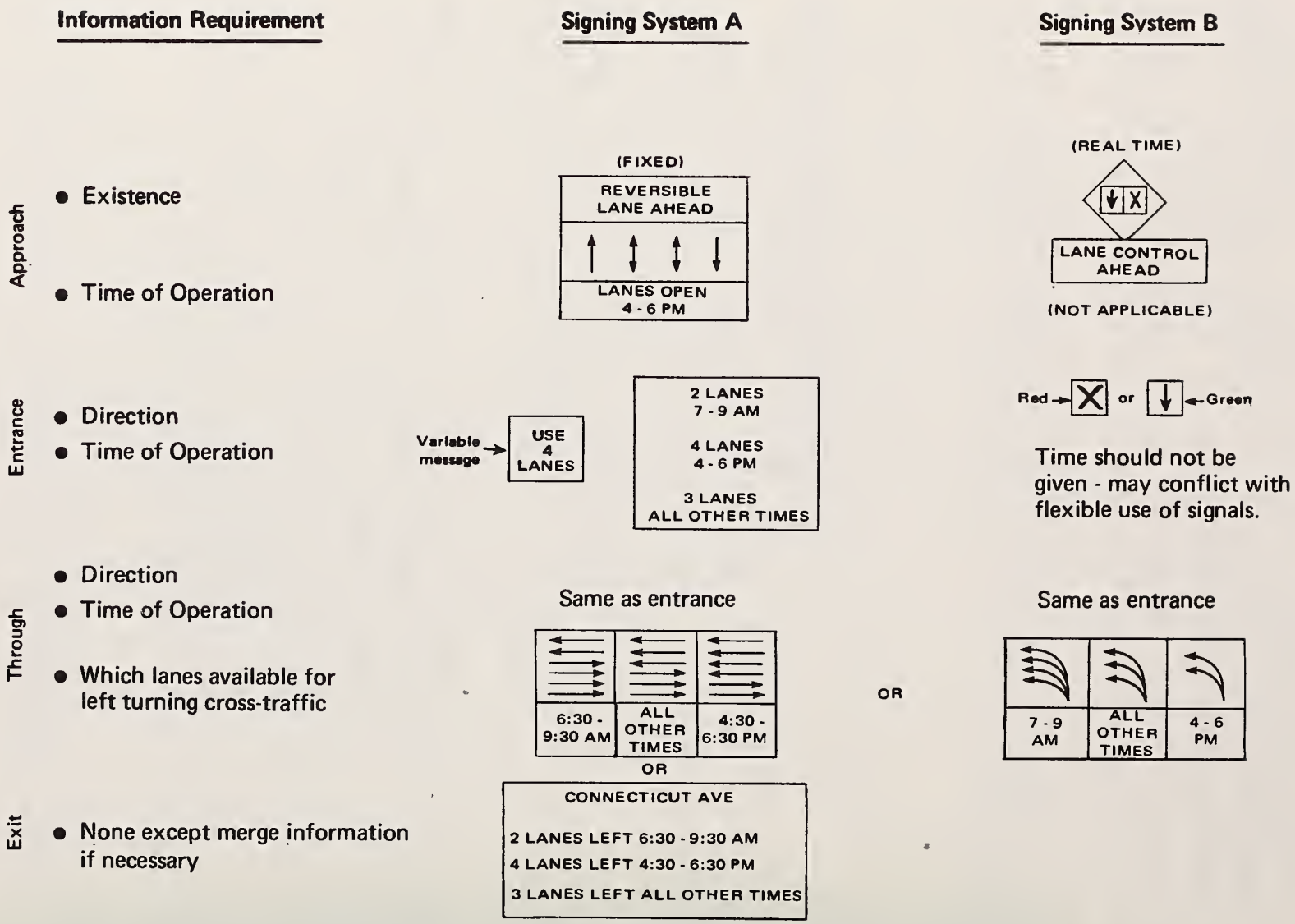
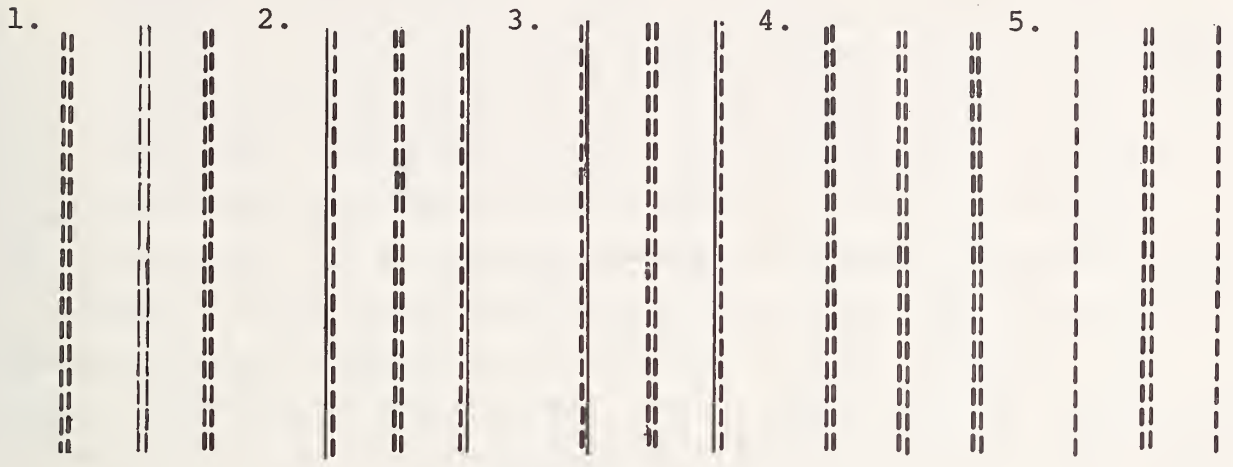


Figure A-9. Possible signing systems for Cell #17.

Possibly more confusion would be created by changing this symbology at this time than beneficial effect to be gained.* However, several alternative systems could be explored. Four possible striping schemes are:



(Note: These are for even number lane facilities — a case not covered in the MUTCD.)

Note that the double arrow on the pavement could be combined with any of the striping schemes or could simply be added to the existing double dash scheme.

Yellow was not recommended by Gordon (1976) for contra-flow designation. This leaves white or some unassigned color for use. White probably is not distinctive enough to be noticed, i.e., few drivers would realize there was a coded meaning among all the white lines. An unassigned color is expensive and would have no inherent meaning, but would be distinctive and drivers would be apt to notice the delineation. However, the drivers would have to learn what the color and the striping configurations mean. This means an education campaign via signs, driver education, and mass media.

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*The discussion and rationale given in Chapter 3 concerning the diamond symbol is equally applicable in this situation.

Conclusion

In this Appendix, signing system options for the ten categories of SUL were discussed. The message content was generally specified to indicate ways the information requirements could be met. However, so many design decisions must be resolved in laboratory study that everything presented here must be considered tentative. For that same reason, specific dimensions and placement along a SUL have not been included. Also, guidance for sign placement (spreading, distance) is given in the MUTCD and various research documents (e.g., McGee et al., 1977; Doughty, 1976), but will be highly site-specific. While an almost infinite variety of signs and messages could be created, those presented were selected with operational feasibility, cost, maintenance, and compatibility with current systems as considerations, along with clearness and conciseness in meeting driver information requirements.

APPENDIX B

WORD INTERPRETATION EXPERIMENT SCENARIOS

CATEGORY I. (HOV)

1. The median lane of an expressway may be used only by buses and taxis with passengers during the hours of 7 to 10 a.m., Monday through Friday. This is a _____ lane.

2. The center lane of a three lane, two-way street is used solely by buses and car pools. During the morning rush hours, the lane moves southbound while during the evening rush hours, the lane moves northbound. This is a _____ lane.

3. Buses and passenger vehicles with 3 or more occupants use the median lane. All other vehicles must use only the shoulder and center lanes. This is a _____ lane.

4. A lane which is to be used only by buses between the hours of 7 a.m. and 9:30 a.m. and may be used by anyone at all other hours. This is a _____ lane.

5. The left lane of a three lane one-way street is assigned to buses only and is indicated as such by signs reading "BUS LANE ONLY" with arrows indicating the lane. This is a _____ lane.

6. The left lane of a three lane expressway is open only to car pools from 6 to 10 a.m. This is a _____ lane.

7. Center lane is for car pools only during the hours of 7 a.m. to 8:30 a.m. and 4 p.m. to 5:30 p.m. This is a _____ lane.

8. During the hours of 6 to 9 a.m. and 4 to 9 p.m., the right lane is limited for use by buses and carpools. Vehicles entering or exiting from the expressway should use the right lane at their entrance or exit only. This is a _____ lane.

9. Only buses and right-turning vehicles are allowed to use right curb lane between 7 a.m. and 5 p.m. All other vehicles must use the left lane. This is a _____ lane.

CATEGORY II. (Restricted by not HOV)

1. A street running one or two blocks in a downtown area is closed to all vehicles. Only pedestrians, therefore, people walking, shopping, etc. are allowed to use it. This is a _____ street.
2. A street is closed as a through route to all normal traffic. Only vehicles having a road use permit are allowed to traverse the road. This is a _____ road.
3. A street is closed to all but local traffic with a sign reading "NOT A THROUGH ROUTE LOCAL TRAFFIC ONLY." This is a _____ street.
4. A shoulder lane is solely for use by bicycles. This is a _____ lane.
5. Access to a street is limited to cars only and is signed to forbid trucks to use the street. This is a _____ street.
6. A road which enters a military base and only vehicles with the required authorization are allowed to use. This is a _____ road.
7. An access road between two directions of an expressway is limited for use by emergency and authorized vehicles. This is a _____ road.
8. On a snow emergency route, no parking is allowed at any time. This is a _____ road.
9. On a three-lane expressway, no pedestrians, bicycles, motor-driven cycles and trucks are allowed. This is a _____ road.
10. The center lane of an undivided street is to be used for left turns only. This is a _____ lane.

11. During the hours of 6 to 9 a.m., the left lane of three lanes is used only by buses which are traveling in a direction opposite to the direction of travel of this otherwise one way road. When this left lane is in operation, signs are posted over this lane to keep opposing traffic out. This is a _____ lane.

CATEGORY III. (Special but not restricted)

1. A reversible lane alternates its direction of travel to increase the capacity of a multi-laned road at a particular time. During the morning rush hour the lane moves south and in the evening moves north. This is a _____ lane.
2. A road marked specifically as a civil defense evaluation route providing access to areas of protection in case of an attack on the area. This is a _____ road.
3. An express road provides a direct route to a particular destination and does not allow exits to local destinations. This is a _____ road.
4. A road designed as a snow emergency route, is given first priority for plowing during snowfall. This is a _____ road.
5. A right lane of an expressway moving through a mountainous region is designated for use by trucks. This is a _____ lane.
6. A service road provides access from a major highway to motels, gas stations, etc. This is a _____ road.
7. A scenic route allows drivers to reach a destination available via other roads but which affords the drivers opportunities to view different historical or beautiful aspects of a scenic area. This is a _____ road.

8. A truck route is an alternative to routes which either have weight limit restrictions or specifically exclude trucks. This is a _____ route.

9. A major highway connecting with an interstate highway and providing access to the business section of a city area is called a business loop route. This route is open to all vehicles and is a _____ road.

10. To cover costs for maintenance and construction, some highways charge tolls at periodic points along the roadway. This is a _____ road.

11. A road through areas where horse powered transportation is used is specifically signed to make drivers aware of that fact. The road is open to all vehicles but requires all drivers to be particularly alert. This is a _____ road.

APPENDIX C

EXPERIMENTAL MATERIALS

Experiment 1: Instructions to Subjects (Task 3)

Part I

Imagine that you are driving down the center lane of an ordinary, 3-lane highway (as shown - Slide #1),

when suddenly you see that something is blocking your way (as shown - Slide #2).

You must now make a choice, to go into the right lane or the left lane, in order to get by.

For each of the following slides, please mark "right" or "left" to show which you think is the lane to take to get around the blockage in your way.

Don't be concerned with what is actually blocking your center lane; all we wish to know is which lane you feel you should take in each slide, right or left. There is no traffic behind you to worry about.

Part II

Imagine you are still driving down the center lane as before. You notice a different stripe pattern on your right. Seeing this, please check all the statements which best describe the right lane to you.

Experiment 1:
Samples from Parts I and II Response Sheets

1. __ Left __ Right
2. __ Left __ Right
3. __ Left __ Right
4. __ Left __ Right
5. __ Left __ Right
6. __ Left __ Right
7. __ Left __ Right
8. __ Left __ Right
9. __ Left __ Right
10. __ Left __ Right
11. __ Left __ Right
12. __ Left __ Right
13. __ Left __ Right
14. __ Left __ Right

26. __ Left __ Right
27. __ Left __ Right
28. __ Left __ Right
29. __ Left __ Right
30. __ Left __ Right
31. __ Left __ Right
32. __ Left __ Right
33. __ Left __ Right
34. __ Left __ Right
35. __ Left __ Right
36. __ Left __ Right
37. __ Left __ Right
38. __ Left __ Right
39. __ Left __ Right

3. _____ I can enter the lane for passing and travel as I wish.

_____ I can enter this lane for turns or exit ramps only.

_____ I would enter this lane only for emergency repairs.

_____ I should not use the right lane: it is reserved for special vehicles only.

_____ I should not use the right lane at all.

_____ I have no idea whether I can enter the right lane or not.

Experiment 2: Instructions to Subjects
(Task 3 - Field Component)

I am going to drive you along some closed sections of highway near here, where there is no traffic. Imagine that we are traveling in the center lane of an ordinary, three lane highway, such as you see in this photograph. (show photo). As we ride along, sometimes you will see some road markings to your right and to your left. As we approach each set of markings, imagine that something is blocking your center lane and you must cross one of these markings to pass to the right or to the left. For each set, please check on your answer sheet whether you would pass by crossing to the left lane or to the right lane.

As we approach each set, I will alert you and call out the number. We won't actually see anything blocking the center, nor will we cross left or right. I am simply interested in which marking you would crossover if you had to leave the center lane at each set point.

Don't feel that there is any traffic in either of the lanes or that what is blocking the center has any significance. All I want to know is, with one marking to your left, and one to your right, which would you cross in order to pass.

Again, I will call out each set number as we approach it.

Any questions?

Subject Response Form

BioTechnology, Inc.
Transportation Research Program

Subject #_____

Route #_____

Day ____ Night ____

1. _____ LEFT _____ RIGHT
2. _____ LEFT _____ RIGHT
3. _____ LEFT _____ RIGHT
4. _____ LEFT _____ RIGHT
5. _____ LEFT _____ RIGHT
6. _____ LEFT _____ RIGHT
7. _____ LEFT _____ RIGHT
8. _____ LEFT _____ RIGHT
9. _____ LEFT _____ RIGHT
10. _____ LEFT _____ RIGHT
11. _____ LEFT _____ RIGHT
12. _____ LEFT _____ RIGHT

Subject Information - Please Fill In

Sex _____ M _____ F

Age _____

PART II

Shown below are drawings of the road markings you have just driven through. If you saw this kind of striping on the right lane of a highway in the real world, check below which of the following statements would describe this lane to you:

1.

_____ I can enter the lane for passing and travel as I wish.

_____ I can enter this lane for turns or exit ramps only.

_____ I would enter this lane only for emergency repairs.

_____ I should not use the right lane: it is reserved for special vehicles only.

_____ I should not use the right lane at all.

_____ I have no idea whether I can enter the right lane or not.

2.

_____ I can enter the lane for passing and travel as I wish.

_____ I can enter this lane for turns or exit ramps only.

_____ I would enter this lane only for emergency repairs.

_____ I should not use the right lane: it is reserved for special vehicles only.

_____ I should not use the right lane at all.

_____ I have no idea whether I can enter the right lane or not.

see next page for no. 3 & 4

3.

_____ I can enter the lane for passing and travel as I wish.

_____ I can enter this lane for turns or exit ramps only.

_____ I would enter this lane only for emergency repairs.

_____ I should not use the right lane: it is reserved for special vehicles only.

_____ I should not use the right lane at all.

_____ I have no idea whether I can enter the right lane or not.

4.

_____ I can enter the lane for passing and travel as I wish.

_____ I can enter this lane for turns or exit ramps only.

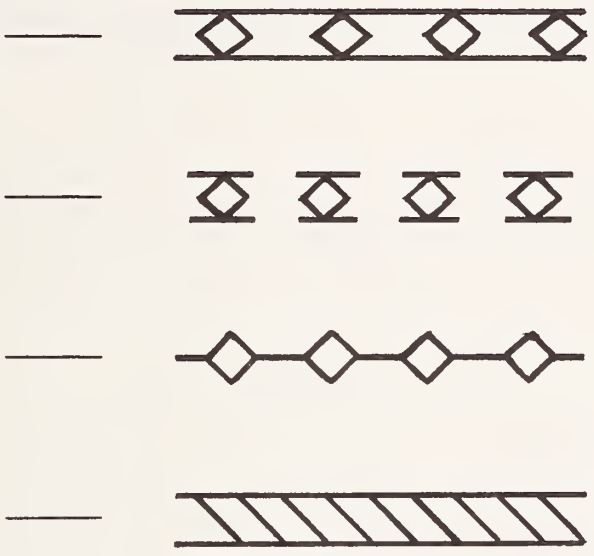
_____ I would enter this lane only for emergency repairs.

_____ I should not use the right lane: it is reserved for special vehicles only.

_____ I should not use the right lane at all.

_____ I have no idea whether I can enter the right lane or not.

Sometimes a highway lane is meant to be reserved for some special use, such as for buses, carpools, bicycles, etc. Given the four kinds of road markings shown below, please rank from 1 to 4 which markings would best mark a special lane apart from the regular lanes. For example, place a number "1" next to the marking which "best" tells you that a certain lane is for special use, and so on to a number "4" for the "worst" marking.



Subject Response Form (continued)

Have you ever seen the diamond symbol used on a roadway or road sign? _____ yes _____ no

If yes, what did it mean (what was it trying to tell you)?

_____

_____

Have you ever seen or driven in a bus/carpool lane?

_____ yes _____ no

Experiment 2: Instructions to Subjects and
Sample Section of Response Sheet
(Task 3 - Laboratory Component)

Instructions to Subjects

Imagine that you are driving down the center lane of an ordinary, 3-lane highway (as shown - Slide #1),

when suddenly you see that something is blocking your way (as shown - Slide #2).

You must now make a choice, to go into the right lane or the left lane, in order to get by.

For each of the following slides, please mark "right" or "left" to show which you think is the lane to take to get around the blockage in your way.

Don't be concerned with what is actually blocking your center lane; all we wish to know is which lane you feel you should take in each slide, right or left. There is no traffic behind you to worry about.

Response Sheets

1.	____Left	____Right	26.	____Left	____Right
2.	____Left	____Right	27.	____Left	____Right
3.	____Left	____Right	28.	____Left	____Right
4.	____Left	____Right	29.	____Left	____Right
5.	____Left	____Right	30.	____Left	____Right
6.	____Left	____Right	31.	____Left	____Right
7.	____Left	____Right	32.	____Left	____Right
8.	____Left	____Right	33.	____Left	____Right
9.	____Left	____Right	34.	____Left	____Right
10.	____Left	____Right	35.	____Left	____Right
11.	____Left	____Right	36.	____Left	____Right
12.	____Left	____Right	37.	____Left	____Right
13.	____Left	____Right	38.	____Left	____Right
14.	____Left	____Right	39.	____Left	____Right

Experiment 4: Instructions to Subjects
(Task 3 - Study #1)

Group I - Bus Drivers

Imagine that you are a city bus driver driving along during rush hour and that you are traveling down the center lane. (Show Slide #1). Next, you see a sign that tells you that there will be a bus lane ahead reserved for your use only. This makes your travel easier since no cars are allowed in this special reserved lane. In the next 66 slides you will see that both curb lanes, the one on the left and the one on the right, are marked off in different ways. As you see each slide, please check on your paper left or right to show which lane you think is the bus lane reserved for you.

Group II - Non-bus Drivers

Imagine that you are driving along in the center lane of a 3-lane city street. (Show Slide #1). Suddenly you must change to either the right lane or the left lane since something is blocking the center (Show Slide #2). You must now make a choice, to go into the right lane or the left lane, in order to get by. For each of the following slides, please mark "Right" or "Left" to show which lane you can take to get by.

Don't be concerned with what is actually blocking your lane; all we wish to know is which lane you feel you should take in each slide, right or left. There is no traffic behind you to worry about.

Response Sheet Used in Experiment 4
(Study #1)

BIOTECHNOLOGY, INC. SUBJECT NO. 38

TRANSPORTATION RESEARCH PROGRAM GROUP NO. _____

PART I

1.	___ LEFT	___ RIGHT	34.	___ LEFT	___ RIGHT
2.	___ LEFT	___ RIGHT	35.	___ LEFT	___ RIGHT
3.	___ LEFT	___ RIGHT	36.	___ LEFT	___ RIGHT
4.	___ LEFT	___ RIGHT	37.	___ LEFT	___ RIGHT
5.	___ LEFT	___ RIGHT	38.	___ LEFT	___ RIGHT
6.	___ LEFT	___ RIGHT	39.	___ LEFT	___ RIGHT
7.	___ LEFT	___ RIGHT	40.	___ LEFT	___ RIGHT
8.	___ LEFT	___ RIGHT	41.	___ LEFT	___ RIGHT
9.	___ LEFT	___ RIGHT	42.	___ LEFT	___ RIGHT
10.	___ LEFT	___ RIGHT	43.	___ LEFT	___ RIGHT
11.	___ LEFT	___ RIGHT	44.	___ LEFT	___ RIGHT
12.	___ LEFT	___ RIGHT	45.	___ LEFT	___ RIGHT
13.	___ LEFT	___ RIGHT	46.	___ LEFT	___ RIGHT
14.	___ LEFT	___ RIGHT	47.	___ LEFT	___ RIGHT
15.	___ LEFT	___ RIGHT	48.	___ LEFT	___ RIGHT
16.	___ LEFT	___ RIGHT	49.	___ LEFT	___ RIGHT
17.	___ LEFT	___ RIGHT	50.	___ LEFT	___ RIGHT
18.	___ LEFT	___ RIGHT	51.	___ LEFT	___ RIGHT
19.	___ LEFT	___ RIGHT	52.	___ LEFT	___ RIGHT
20.	___ LEFT	___ RIGHT	53.	___ LEFT	___ RIGHT
21.	___ LEFT	___ RIGHT	54.	___ LEFT	___ RIGHT
22.	___ LEFT	___ RIGHT	55.	___ LEFT	___ RIGHT
23.	___ LEFT	___ RIGHT	56.	___ LEFT	___ RIGHT
24.	___ LEFT	___ RIGHT	57.	___ LEFT	___ RIGHT
25.	___ LEFT	___ RIGHT	58.	___ LEFT	___ RIGHT
26.	___ LEFT	___ RIGHT	59.	___ LEFT	___ RIGHT
27.	___ LEFT	___ RIGHT	60.	___ LEFT	___ RIGHT
28.	___ LEFT	___ RIGHT	61.	___ LEFT	___ RIGHT
29.	___ LEFT	___ RIGHT	62.	___ LEFT	___ RIGHT
30.	___ LEFT	___ RIGHT	63.	___ LEFT	___ RIGHT
31.	___ LEFT	___ RIGHT	64.	___ LEFT	___ RIGHT
32.	___ LEFT	___ RIGHT	65.	___ LEFT	___ RIGHT
33.	___ LEFT	___ RIGHT	66.	___ LEFT	___ RIGHT

Experiment 4: Instructions to Test Subjects
(Task 3 - Study #2)

Imagine that you are driving down the center of this highway. (Show Slide #1). Suddenly you feel that your car is about to break down, and you need to pull off onto the right or left shoulder. In the next set of 28 slides, we have changed the road markings to your left and to your right. For each slide, please check left or right to show which marking would best mark off a shoulder to you. Do not pay attention to the actual shoulders on the far right and the far left; all we wish to know is which lane, left or right, is best marked as a shoulder to you.

Experiment 4: Sample Answer Sheet
(Task 3, Study #2)

PART II

1.	___ LEFT	___ RIGHT	15.	___ LEFT	___ RIGHT
2.	___ LEFT	___ RIGHT	16.	___ LEFT	___ RIGHT
3.	___ LEFT	___ RIGHT	17.	___ LEFT	___ RIGHT
4.	___ LEFT	___ RIGHT	18.	___ LEFT	___ RIGHT
5.	___ LEFT	___ RIGHT	19.	___ LEFT	___ RIGHT
6.	___ LEFT	___ RIGHT	20.	___ LEFT	___ RIGHT
7.	___ LEFT	___ RIGHT	21.	___ LEFT	___ RIGHT
8.	___ LEFT	___ RIGHT	22.	___ LEFT	___ RIGHT
9.	___ LEFT	___ RIGHT	23.	___ LEFT	___ RIGHT
10.	___ LEFT	___ RIGHT	24.	___ LEFT	___ RIGHT
11.	___ LEFT	___ RIGHT	25.	___ LEFT	___ RIGHT
12.	___ LEFT	___ RIGHT	26.	___ LEFT	___ RIGHT
13.	___ LEFT	___ RIGHT	27.	___ LEFT	___ RIGHT
14.	___ LEFT	___ RIGHT	28.	___ LEFT	___ RIGHT

Experiment 4: Instructions to Subjects
(Task 3, Study #3)

Imagine that you are driving down the center of a 3-lane, one-way city street. (Show Slide #1). Then, up ahead you see a change in the kind of markings in your right hand lane. (Show Slide #2). Now you need a sign to tell you about this right lane. The next slide you will see contains 4 signs with numbers beneath them, 1, 2, 3, and 4. On your answer sheet, please mark the number of the sign that you think goes with the lane on the right. Then, in the space provided write in what the lane is for and who can use it. (Go through 2 examples).

Experiment 4: Answer Sheet
(Task 3, Study #3)

BioTechnology, Inc.
Transportation Research Program

Subject No. 3

Part III

1. Sign # What is it for and who can use it?

   1 2 _____

   3 4 _____

2. Sign # What is it for and who can use it?

   1 2 _____

   3 4 _____

3. Sign # What is it for and who can use it?

   1 2 _____

   3 4 _____

4. Sign # What is it for and who can use it?

   1 2 _____

   3 4 _____

5. Sign # What is it for and who can use it?

   1 2 _____

   3 4 _____

6. Sign # What is it for and who can use it?

   1 2 _____

   3 4 _____

7. Sign # What is it for and who can use it?

   1 2 _____

   3 4 _____

Experiment 4: Additional Questions and
Subject Information
(Task 3, All Studies)

1. Have you ever seen or driven in a bus/carpool lane?

   Yes _____ No _____

   If yes, where? _____

2. Do you think reserved lanes for buses and carpools are a good idea?

   Yes _____ No _____

3. Do you ordinarily ride a bus, or in a group, to work, school, around town, or drive alone in your own car?

   Bus or Group _____ Drive Alone Mostly _____

4. Sex _____M _____F

5. Age _____

APPENDIX D

INSTRUCTIONS TO SUBJECTS AND SUBJECT RESPONSE FORM

Experiment 4: Evaluation of Sign Format and Information Load

BioTechnology is performing this research study under the sponsorship of the Federal Highway Administration. The study is concerned with highway signs which inform drivers of the existence and operation of special usage lanes. These are lanes reserved at certain times for certain vehicles (such as buses, taxis, carpools, etc.). The slides you will see will give information about:

1. Where the lane is located
2. What types of vehicles are permitted to use the lane
3. What hours the lane is open
4. What days the lane is open.

When each slide is shown, please check on your answer sheet the information you see; location, vehicle type, times, and days.

In some cases you will be shown two slides before you fill in the answer sheet; in other cases, you will see only one slide before you fill in the answer sheet.

Before the actual study begins, we will show you 6 practice signs to acquaint you with the format.

PLEASE NOTE: It is important that you mark an answer for <u>every</u> slide. Our data is useless if you leave a blank, so please given an answer in <u>all</u> cases, even if it is a guess.

END OF SLIDES: After all slides have been shown, please fill in the subject information sheet located at the back of the answer booklet. No names or identifying numbers are needed.

SIGN # 65

Lane Information

- [x] - Right Lane
- [ ] - Left Lane
- [ ] - Center Lane

Time Information (Day)

- [ ] - Mon. - Fri.
- [ ] - Sat. - Sun.

Vehicle Type Information

- [x] - Buses
- [x] - 2 Person Car Pool
- [x] - 3 Person Car Pool
- [x] - 4 Person Car Pool
- [x] - Taxi's
- [ ] - Right Turn Vehicles
- [ ] - Left Turn Vehicles

Time Information (Hours)

a.m. Start Hour	a.m. End Hour	p.m. Start Hour	p.m. End Hour
[ ] - 6:30	[ ] - 9:00	[ ] - 3:30	[ ] - 6:00
[ ] - 7:00	[ ] - 9:30	[ ] - 4:00	[ ] - 6:30
[ ] - 7:30	[ ] - 10:00	[ ] - 4:30	[ ] - 7:00
[ ] - 8:00	[ ] - 10:30	[ ] - 5:00	[ ] - 7:30

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FORMERLY FORM

FEDERALLY COORDINATED PROGRAM (FCP) OF HIGHWAY RESEARCH AND DEVELOPMENT

The Offices of Research and Development (R&D) of the Federal Highway Administration (FHWA) are responsible for a broad program of staff and contract research and development and a Federal-aid program, conducted by or through the State highway transportation agencies, that includes the Highway Planning and Research (HP&R) program and the National Cooperative Highway Research Program (NCHRP) managed by the Transportation Research Board. The FCP is a carefully selected group of projects that uses research and development resources to obtain timely solutions to urgent national highway engineering problems.*

The diagonal double stripe on the cover of this report represents a highway and is color-coded to identify the FCP category that the report falls under. A red stripe is used for category 1, dark blue for category 2, light blue for category 3, brown for category 4, gray for category 5, green for categories 6 and 7, and an orange stripe identifies category 0.

FCP Category Descriptions

1. Improved Highway Design and Operation for Safety

Safety R&D addresses problems associated with the responsibilities of the FHWA under the Highway Safety Act and includes investigation of appropriate design standards, roadside hardware, signing, and physical and scientific data for the formulation of improved safety regulations.

2. Reduction of Traffic Congestion, and Improved Operational Efficiency

Traffic R&D is concerned with increasing the operational efficiency of existing highways by advancing technology, by improving designs for existing as well as new facilities, and by balancing the demand-capacity relationship through traffic management techniques such as bus and carpool preferential treatment, motorist information, and rerouting of traffic.

3. Environmental Considerations in Highway Design, Location, Construction, and Operation

Environmental R&D is directed toward identifying and evaluating highway elements that affect the quality of the human environment. The goals are reduction of adverse highway and traffic impacts, and protection and enhancement of the environment.

4. Improved Materials Utilization and Durability

Materials R&D is concerned with expanding the knowledge and technology of materials properties, using available natural materials, improving structural foundation materials, recycling highway materials, converting industrial wastes into useful highway products, developing extender or substitute materials for those in short supply, and developing more rapid and reliable testing procedures. The goals are lower highway construction costs and extended maintenance-free operation.

5. Improved Design to Reduce Costs, Extend Life Expectancy, and Insure Structural Safety

Structural R&D is concerned with furthering the latest technological advances in structural and hydraulic designs, fabrication processes, and construction techniques to provide safe, efficient highways at reasonable costs.

6. Improved Technology for Highway Construction

This category is concerned with the research, development, and implementation of highway construction technology to increase productivity, reduce energy consumption, conserve dwindling resources, and reduce costs while improving the quality and methods of construction.

7. Improved Technology for Highway Maintenance

This category addresses problems in preserving the Nation's highways and includes activities in physical maintenance, traffic services, management, and equipment. The goal is to maximize operational efficiency and safety to the traveling public while conserving resources.

0. Other New Studies

This category, not included in the seven-volume official statement of the FCP, is concerned with HP&R and NCHRP studies not specifically related to FCP projects. These studies involve R&D support of other FHWA program office research.

* The complete seven-volume official statement of the FCP is available from the National Technical Information Service, Springfield, Va. 22161. Single copies of the introductory volume are available without charge from Program Analysis (HRD-3), Offices of Research and Development, Federal Highway Administration, Washington, D.C. 20590.

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